2

UNITED STATES DEPARTMENT OF AGRICULTURE

3 SURVEY REPORT

WATERSHED OF THE LITTLE SIOUX RIVER

(Iowa & Minnesota)

U.S.D.A. Survey Report

Program for Watershed Improvement
in Aid of Flood Control

Pursuant to Section 6 of the Flood Control Act, June 22, 1936, Public 738, 74th Congress, Public 406, 75th Congress, August 28, 1937

MAY 1 1943

CONTENTS

SUMMARY

In compliance with the Flood Control Act of 1936 and subsequent related legislation the U. S. Department of Agriculture conducted a survey of the watershed of the Little Sioux River. The findings of this survey are briefly summarized below and given in greater detail in the body of this report.

The Watershed and the Problem

The Little Sioux River rises in southwestern Minnesota and flows in a southwesterly direction to enter the Missouri River about halfway between Sioux City and Council Bluffs, Iowa. The entire watershed contains 4,502 square miles, more than 93 percent of which lies within the State of Iowa. The upper third of the watershed lies in a glaciated region and contains a considerable number of lakes. Wind blown material, or loess, has covered the lower part of the watershed, producing soils of exceptional productivity. The topography of the loess covered area varies from gently rolling throughout the central portion of the basin to precipitous in the bluffs bordering the Missouri River alluvial plain. Practically all of the watershed is in farms and about one-half of the land is used for the production of corn and small grain.

Flood run-off originating on the loess covered portion of the Little Sioux watershed is responsible for damages considerably in excess of one-half million dollars each year. In the main these damages are the result of (a) discharge of flood waters and sediment upon the rich alluvial plain bordering the Missouri River; (b) flood overflows along all upland streams and (c) the rapid growth of trench type gullies of great depth. In addition flood run-off removes large quantities of fertile top soil from the upland farms, thus bringing about the gradual deterioration of an irreplacable natural resource.

Recommended Program

The remedial program designed for abating the flood and related damages mentioned above consists of two phases: (1) The treatment of farmlands in the loess covered portion of the watershed below Clay and Osceola Counties, Iowa, to reduce flood run-off at its source and minimize erosion; and (2) the building of structures to control major gullies; that is, gullies so large that they cannot be stopped by individual action.

The proposed farmland treatment measures are directed toward increasing the proportion of the watershed protected by grass and other close growing covers and assisting the farmers to put into effect improved agricultural practices. Both of these things will increase the amount of storm rainfall taken into the soil during flood periods and will thus reduce both flood run-off and erosion. The more important of the measures contemplated are: (a) The placing of lands too steep for cultivation under permanent protective covers such as grass and trees; (b) the use of soil and water-conserving rotations, including winter cover crops; (c) the improvement, protection and management of pastures and woodlots; and (d) supplementary measures such as terracing, contour furrowing, tree planting, refencing, gully control and waterway protection.

To control the major gullies it is proposed to build earth dams at strategic points and to install flumes and other structures to convey the flood waters safely to the bottoms of the gullies. Many of these earth dams will also take the place of bridges now being maintained at great expense.

The program described above is to be applied to that portion of the watershed lying below Clay and Osceola Counties and above the Missouri River alluvial plain. This area was divided into two main divisions for purposes of designing and evaluating the remedial program. Division A (see Figure 1) includes the upper 45 percent of the area to be treated and is to receive farm land treatment only. In Division B both the farm land treatment measures and the major gully control works are to be installed.

It is recommended that the sum of $4,280,000 of Federal funds be expended to install this program, pursuant to the Flood Control Act of 1936, provided: (a) that a local agency (or agencies) acceptable to the Secretary of Agriculture agrees to contribute the sum of $368,000 toward the construction of earth dams in major gullies or agrees to place one-half of the earth fill required in the construction of these dams, and (b) that a local agency (or agencies) acceptable to the Secretary of Agriculture agrees to inspect, operate, repair, replace and otherwise maintain the major control gully works in perpetuity.

It is expected that the normal expenditures of the Department of Agriculture will continue to be made in the watershed under the Soil Conservation and Agricultural Conservation Programs, and that these expenditures will bring about the installation of a portion of the work contemplated under this plan. Requests for future appropriations to finance the program herein described will, of course, take account of whatever progress has been made toward installation of the program through Department expenditures under its regular programs.

<u>Distribution of Costs</u>: The measures recommended for installation and the amount of Federal funds required for each program are as follows:

1.	Farm land treatment	$1,872,057
2.	Major gully control	2,411,580

In addition farmers and other individuals must contribute an estimated $1,259,120 in the form of labor and materials to install the farm land treatment program and State or local agencies must contribute an estimated $368,000 in the form of labor and equipment for earth fills to install dams in the major gully control program that will replace existing bridge crossings.

The Federal Government will incur no costs for the operation and maintenance of either of the programs.

The cost of maintaining the program in Division A would amount to $570,687 annually, all of which would be borne by the farmers. In

Division B the farmers would maintain the farm land treatment measures at an annual cost of $528,057 and a suitable State or local agency (or agencies) would maintain the major gully control works; a responsibility that will require an annual expenditure averaging about $20,000.

In deriving the above costs it was assumed that 70 percent of the farmers would participate in the farm land treatment phase of the program and that all major gullies would be controlled.

Economic Justification: It is estimated that the program will yield the following average annual direct benefits:

Reduction of flood damages to crops and pasture	$ 38,511
Reduction of flood damage to fences, highways and railroads	12,659
Reduction of sedimentation damage to drainage ditches	18,263
Reduction of damage to land by major gullies	184,546
Total flood control benefits	253,979
Increase in farm income (on-site benefits)	2,627,290
Total average annual benefits	$2,881,269

Average annual costs and benefits of the program are as follows:

Average Annual Costs and Benefits

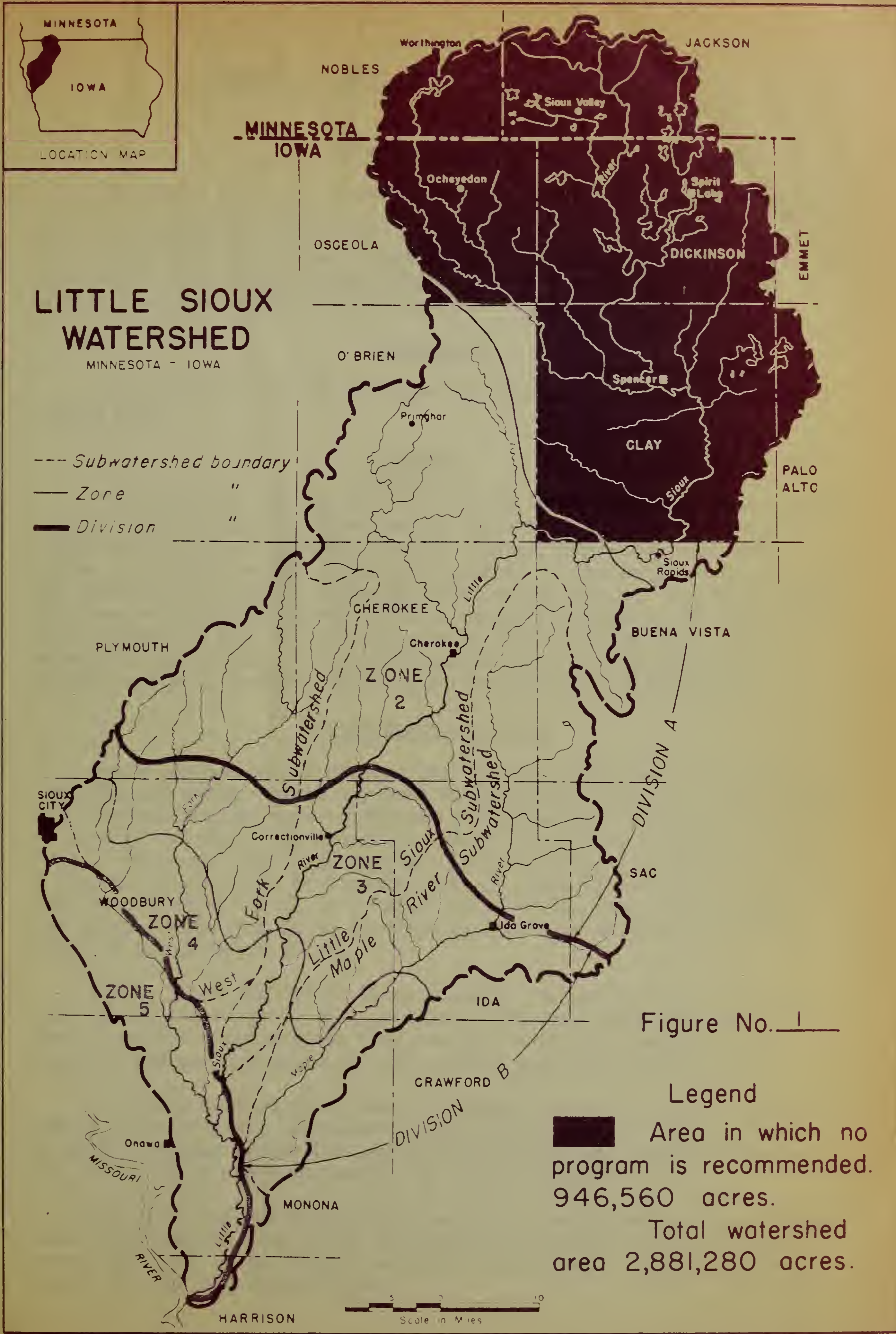
Watershed Division	Annual Benefits		Annual Costs		Benefit Per Dollar Total Cost	Flood Control Benefit per Dollar Federal Cost
	Total	Flood Control	Total	Federal		
A	1,517,600	31,700	617,000	27,800	2.46	1.14
B	1,363,700	222,300	708,400	122,000	1.92	1.82
Total	2,881,300	254,000	1,325,400	149,800	2.17	1.69

FOREWORD

At the outset of the Survey preliminary studies were made of the flood problems of the entire Little Sioux watershed and consideration was given to possible programs for abating flood damages. As a result it was concluded that treatment of the glaciated area in the extreme headwaters (Zones 0 and 1 of Figure 1) would not produce sufficient flood benefits to warrant further investigation. Accordingly a detailed survey was made of only that portion of the watershed lying below the glaciated area.

In evaluating the program recommended in this Report benefits were derived for the treatment of Zones 2, 3 and 4 of Figure 1. Upon finding that the treatment of each of these zones could be justified it was felt advisable, in the interest of simplifying administrative arrangements, to provide a more definite upper limit for the area eligible to receive treatment. A sensible choice seemed to be the south and west boundaries of Clay County and the south boundary of Osceola County. Adopting this upper limit the final evaluations of costs and benefits were made for two Divisions of the watershed; Division A, comprising all of the land lying below Clay and Osceola Counties and above the lower boundary of Zone 2; and Division B, including Zones 3 and 4 of Figure 1.

The damages caused by stream overflow, and the benefits derived from reducing such damages, must be developed by watersheds rather than by Zones or Divisions. Such damages and benefits were, therefore, calculated separately for the following subwatersheds: (a), The Little Sioux above Zone 5 and below the upper limit of Zone 2; (b), Maple River above Zone 5, and; (c), the West Fork above Zone 5 (including all tributaries to the West Fork).


LITTLE SIOUX WATERSHED
MINNESOTA - IOWA
LOCATION MAP
MINNESOTA
IOWA
NOBLES
JACKSON
Worthington
Sioux Valley
MINNESOTA
IOWA
Ocheyedan
Spirit Lake
OSCEOLA
DICKINSON
EMMET
O' BRIEN
Spencer
Primghar
CLAY
PALO ALTO
Sioux Rapids
CHEROKEE
BUENA VISTA
PLYMOUTH
Cherokee
ZONE 2
SIOUX CITY
Correctionville
ZONE 3
SAC
WOODBURY
ZONE 4
Ida Grove
ZONE 5
IDA
CRAWFORD
DIVISION A
DIVISION B
Onawa
MISSOURI RIVER
MONONA
HARRISON
Scale in Miles
--- Subwatershed boundary
— Zone "
Division "
Figure No. 1
Legend
Area in which no program is recommended. 946,560 acres.
Total watershed area 2,881,280 acres.

L-3019-V

SECTION I - DESCRIPTION OF THE WATERSHED

Location and Size

The Little Sioux River drains a total area of 4502 square miles, of which 4197 square miles are in northwestern Iowa and 305 square miles are in southwestern Minnesota. The long, narrow basin extends about 135 miles northeast of the confluence of the Little Sioux River with the Missouri River at River Sioux, Iowa. It has a maximum width of 50 miles at a point about 50 miles above the mouth. (Figure 1)

Population

The population of the watershed is 125,000, an average of 28 per square mile.

Climate

The climate of the region is favorable to agriculture. The average annual precipitation is approximately 28 inches, 75 percent of which falls during the crop-growing season. Only a three-inch variation exists in average rainfall from the southern to the northern portion of the watershed, the range being 27 inches to 30 inches. The mean annual air temperature is 47 degrees with an average maximum of 58 and an average minimum of 36. The average growing season is 151 days. The warmest month is July, with a mean temperature of 74 degrees and the coldest month is January, with a mean temperature of 18 degrees.

Physiography and Soils

The watershed can be divided into six physical zones (See Figure 1). Proceeding downstream from the head of the basin: Zone 0 is the irregular terminal moraine area developed by the Wisconsin glacier; Zone 1 is an area of relatively smooth glacial drift; Zone 2 is a gently rolling area on which the soils are predominately of loessial origin; Zone 3 is a steeply rolling area of loessial soil in which slopes of 8 to 15 percent predominate; Zone 4 is a "bluff area" of loessial soil in which the slopes range from 15 to 50 percent; Zone 5 is part of the alluvial plain of the Missouri River.

The soils of the Little Sioux Basin may be divided into three general groups according to the parent material from which they have developed — upland soils derived from loessial materials, upland soils derived from glacial material, and terrace and first bottom soils.

The soils derived from loess constitute the most extensive group of upland soils covering approximately 2290 square miles. These soils are in general highly productive except where the slopes exceed 15 percent. The steeper land has been subject to severe erosion.

The soils derived from glacial material are in general less rolling than those derived from loess, and, except in limited areas of sandy or gravelly material, are highly productive if drained. Erosion is less severe than in the loessial area.

The soils of the bottomland and terrace group, except those of sandy texture, are inherently productive. Drainage is required in the Missouri River alluvial plain area.

Vegetation

Prior to its settlement by the white man most of the Little Sioux Watershed was covered with native prairie grasses. At the present time it is a highly developed agricultural area and practically all of the land is in farms.

For the watershed as a whole, corn is the leading crop followed in importance by small grain. About half of the uplands are used for the production of these two crops.

The predominant meadow crop in the southern portion of the area is sweet clover. A small amount of the brome grass and alfalfa is also grown in this area. In the northern section alfalfa and red clover are the predominate meadow crops.

A part of the bluff area of Woodbury, Monona and Harrison counties consists of slopes too steep for cultivation. The prevailing vegetation on these slopes is native prairie grass consisting in the main of big bluestem, little bluestem, and side oats grama. About 70 percent of this cover is poor to fair and affords little protection to the land.

The small amount of permanent tame pasture found in the watershed occupies the poorly drained draws and the steep areas along the rivers.

The amount of woodland in the watershed is relatively small and is largely restricted to the river valleys and to the north and east slopes of the loessial bluffs. Practically all of the timberland is grazed and affords little watershed protection.

Channel Characteristics

There is considerable variation in stream channel gradient among the tributary watersheds studied. The Little Sioux proper has an average fall of approximately 1.7 feet per mile, through the flood damage area. Gradients through the flood damage area on the smaller tributaries are approximately as follows: Maple River 5.5 feet per mile, West Fork 6.3 feet per mile, Elliott Creek 8.3 feet per mile. Where these streams enter the Missouri River Flood Plain, there is an abrupt change in channel gradient. From this point to their confluence with the Missouri River the gradient is approximately 1 foot per mile. This abrupt change in gradient causes the deposition of large quantities of sediment in Zone 5.

Types of Farms

Mixed livestock and hog farming predominates in the watershed. However, cash grain farms, cattle or sheep feeding farms, and cattle raising farms are found throughout the watershed. Grain is sold from two-thirds of the farms but brings in only about one-sixth of the total income.

Farm Sizes and Incomes

The average farm contains about 200 acres. There are relatively few farms as small as 80 acres, or larger than 400 acres.

The average net cash income per farm in the watershed in 1939 was $1493, with a range of from $4297 to $112. The average farm income in the gently-rolling area is about $1700 whereas in the steeply rolling and bluff area the average is only $1100.

Tenancy

The proportion of tenancy in the various counties of the watershed ranged from 57 to 63 percent during the period 1928-38. In addition to this, the percentage of part renters was between 8 and 9. Although there is some cash renting, especially on the better land, and a small number of stock share leases, most of the renting is done on a crop share basis. About one-fifth of the renting arrangements are between relatives. The proportion of renters moving in any year is not high. The usual term of leasing, however, is on a year-to-year basis.

Area of Watershed Subdivisions

The areas of the principal subdivisions of the watershed used in designing and evaluating the program recommended in this report are summarized below:

Total area in Little Sioux Watershed		4502.3	square miles
Area of Division A		1490.5	" "
Area of Division B		1229.6	" "
Total area to receive treatment under program		2720.1	" "
Areas in Zones			
Zone 0		780.6	" "
Zone 1		747.7	" "
Zone 2		1441.2	" "
Zone 3		659.4	" "
Zone 4		570.2	" "
Zone 5 (Missouri River Alluvial Plain)		303.2	" "
Areas of Subwatersheds by zones			
Little Sioux Subwatershed			
Zone 2	785.7		
Zone 3	221.4		
Zone 4	106.6		
Total		1113.7	
Maple River Subwatershed			
Zone 2	372.6		
Zone 3	226.5		
Zone 4	140.9		
Total		740.0	
West Fork Subwatershed			
Zone 2	282.9		
Zone 3	211.5		
Zone 4	183.2		
Total		677.6	
Areas of other watersheds used in evaluation			
West Fork (proper)		395.0	
Elliott Creek		58.5	
Area of small tributaries not draining into any of the three major subwatersheds		139.5	

SECTION II - FLOOD PROBLEMS AND DAMAGES

Flood and Related Problems

Flood run-off in the Little Sioux watershed is responsible for a number of problems. The most serious of these are briefly described below:

1. Damage to Drainage District Lands: As will be seen from Figure 1 the streams of the watershed discharge upon the alluvial plain of the Missouri River. To enable this area of rich soil to be farmed, drainage districts were formed and ditches constructed. The flood waters discharged into these ditches by the Little Sioux and its tributaries frequently break out and inundate large areas of cropland. Moreover, the large quantities of sediment brought down from the eroding uplands fill the ditches and must be removed at great expense to the drainage districts. More than one-fourth of all the damages attributable to floods originating on the Little Sioux watershed are experienced on this alluvial bottom.

2. Overflow of Main Stem Bottoms: Floods regularly inundate the rich bottomland along the main watercourses of the upland area causing much damage to crops and pastures. Such losses are particularly high along the lower 25 miles of the Little Sioux itself where they average about 2300 dollars per mile of valley every year.

3. Damage by Major Gullies: In the lower portion of the basin (Zones 3 and 4 of Figure 1) trench type gullies of great depth are advancing into upland farms, forcing the abandonment of large areas of productive land and making necessary the construction and maintenance of numerous bridges. These gullies are developed by flood run-off from areas ranging in size from 1 to 10 square miles and thus the owners of the farms first damaged have no control over the lands on which the run-off originates. Once such a gully is well started it becomes impossible for the individual landowners to check its progress and public action is required to avoid the eventual loss of the entire contributing area.

4. Damages in Minor Streams: Throughout the area surveyed frequent floods are experienced in small watercourses. In the aggregate the damage caused by these floods is surprisingly high; on some watersheds exceeding the damage along the main stem.

5. Erosion of Farmlands: Erosion of the productive surface soil from upland farms is another serious problem related to floods, in that the soil is removed by flood waters on their way to the main watercourses.

The three subwatersheds selected for the evaluation of flood and related benefits were: The watershed of the Little Sioux itself below Zone 1; the watershed of Maple River; and the West Fork and all of its

tributaries. The principal damages chargeable to the run-off and sediment coming from these watersheds are:

(a) For the Little Sioux - The high damages caused by inundation of crops and pastures in the lower reaches of the main stem.

(b) For the Maple River - The damages to lands and bridges by the major gullies of Zones 3 and 4; about half of all attributable damage being chargeable to this source.

(c) For the West Fork - The damages to drainage districts on the Missouri River alluvial plain; more than three-fourths of all the damages suffered by these districts being chargeable to water and sediment discharged by the West Fork and its tributaries.

Flood Damages in Zones 2, 3 and 4

The principal flood damages experienced upstream from the Missouri River alluvial plain are of the following kinds:

1. Damage to crops and pastures by water and sediment.

2. Damage to fences, highways and railroads.

3. Damage caused by major gullies.

Damage to Crops and Pastures

The damages to crops and pastures along the main streams were estimated by the following procedure:

a. By using information obtained from flood plain farmers, the damage done to crops and pasture by inundation to various depths and for various periods of time were determined for the Little Sioux, Maple, West Fork and Elliott main stems.

b. The areas that would be inundated by floods of selected magnitude were determined for various reaches of the stream by hydraulic calculations.

c. The durations of inundation on various parts of the flood plain were estimated for selected floods.

d. With the data itemized above, curves were constructed showing, by seasons, the damage that would be done in selected reaches of the stream by a flood reaching any peak at the lower end of the subwatershed.

e. An evaluation series of floods was derived for each subwatershed; that is, the floods to be expected during a selected period of years (15 years on the Little Sioux and Maple and 16 years on West Fork and Elliott Creek).

f. The damage that would be caused by each of the floods in the evaluation series was determined by use of the curves showing the relations between discharge and damage; approximate corrections being made for the effect of previous floods in reducing the value of crops in the flood plain.

g. The average annual damage was determined by summing the damages done by each flood in the evaluation series and dividing by the number of years in the evaluation period.

This procedure is explained in detail in Appendix B and the calculations of average annual damage are given therein.

Damages to crops and pastures include those caused by inundation by flood waters for the duration of such inundations and those caused by flood borne sediment. This sediment causes a reduction in yields, loss of fertility of agricultural lands and a reduction of agricultural acreage through the deposition of sterile debris.

The damages to crops and pastures in minor tributaries were estimated by obtaining schedules of flood damage through field appraisals at half mile intervals along all of the named streams in the area surveyed.

Damage to Fences, Highways and Railroads

Damages to fences, highways and railroads were estimated by field appraisals at the time the information on crop and pasture damage was obtained. Most of the damage to highways and railroads is a result of sediment deposition.

Damage Caused by Major Gullies

The annual damage caused by major gullies will vary in the future because gully systems develop at an accelerating rate until the drainage area becomes thoroughly dissected and then, as the areas contributing run-off to the lateral gullies become smaller and smaller, the rate of development decreases. Because of the variation of damage with time it is necessary to discount all future damages to their present value, year by year, and to sum these annual values to obtain the total monetary damage. To make this possible it was necessary to predict the rates at which lands in the gullied watersheds would be damaged in the future.

As a basis for predicting future rates of land damage a study was made of 29 sample gully systems chosen at random within zones especially delineated for sampling. Through a field survey the following data were collected for the eleven samples on which public action would clearly be required to control the gully:

1. Area of contributing watershed

2. Area of land destroyed (engulfed) by the gully system.

3. Area of land forced into a less remunerative use by action of the gully and thus depreciated in value.

4. Value of undepreciated lands.

5. Value of depreciated lands.

6. Approximate age of the gully system.

After a study of these data, and of the general history of more fully developed gullies in other parts of the United States, it was concluded that the gully systems of this area would develop in a manner that can be expressed by an equation of the type:

$$\text{Cumulative effect} = \frac{1}{1 + C\,e^{-kt}}$$

in which C and k are constants and t represents the age of the system. By use of the data collected the constants in the above equation were evaluated resulting in the expression:

$$\text{Percent of contributing area damaged}^{(1)} = \frac{100}{1 + 1000\,e^{-.07t}}$$

This expression gives the cumulative area damaged at any time for a gully system of average characteristics. It can also be used to calculate the areas affected annually. Both the cumulative and annual effects for an average gully system are depicted by Figure 2.

The damage done to an acre of land affected by any gully was taken as the difference between the present value of undamaged lands and the reduced value of depreciated lands. It is clear that the actual damage would be greater than this amount as part of the area is eventually "destroyed", at which time the damage becomes full value of the land. However, since this additional damage is relatively small and since its omission only makes the benefits claimed for the program recommended to reduce damages more conservative no attempt was made to evaluate it.

For each sample watershed the acres damaged each year were obtained from the curve of Figure 2 and the unit losses in value arising from depreciation were applied against these acreages. The damage for each year was then reduced to its present values and summed by a graphical procedure. Inasmuch as the present value of damage experienced late in the life of a gully system becomes vanishingly small, the estimate of total damage derived by this procedure is equivalent, for all practical purposes, to that for an infinite period of time. The average annual damage can, therefore, be obtained by simply multiplying the total damage by the interest rate used (3.5 percent).

For each group of gullies representing a selected zone the damage were summed and divided by the combined areas of the samples. The damages per unit area thus derived was applied against the total area in each of the sampled zones. The sum of the damages in these zones represents the total damage in Division B, as all of the sampling zones in which major gully damage was found lie within this Division.

---

(1) Includes both area destroyed and area depreciated.

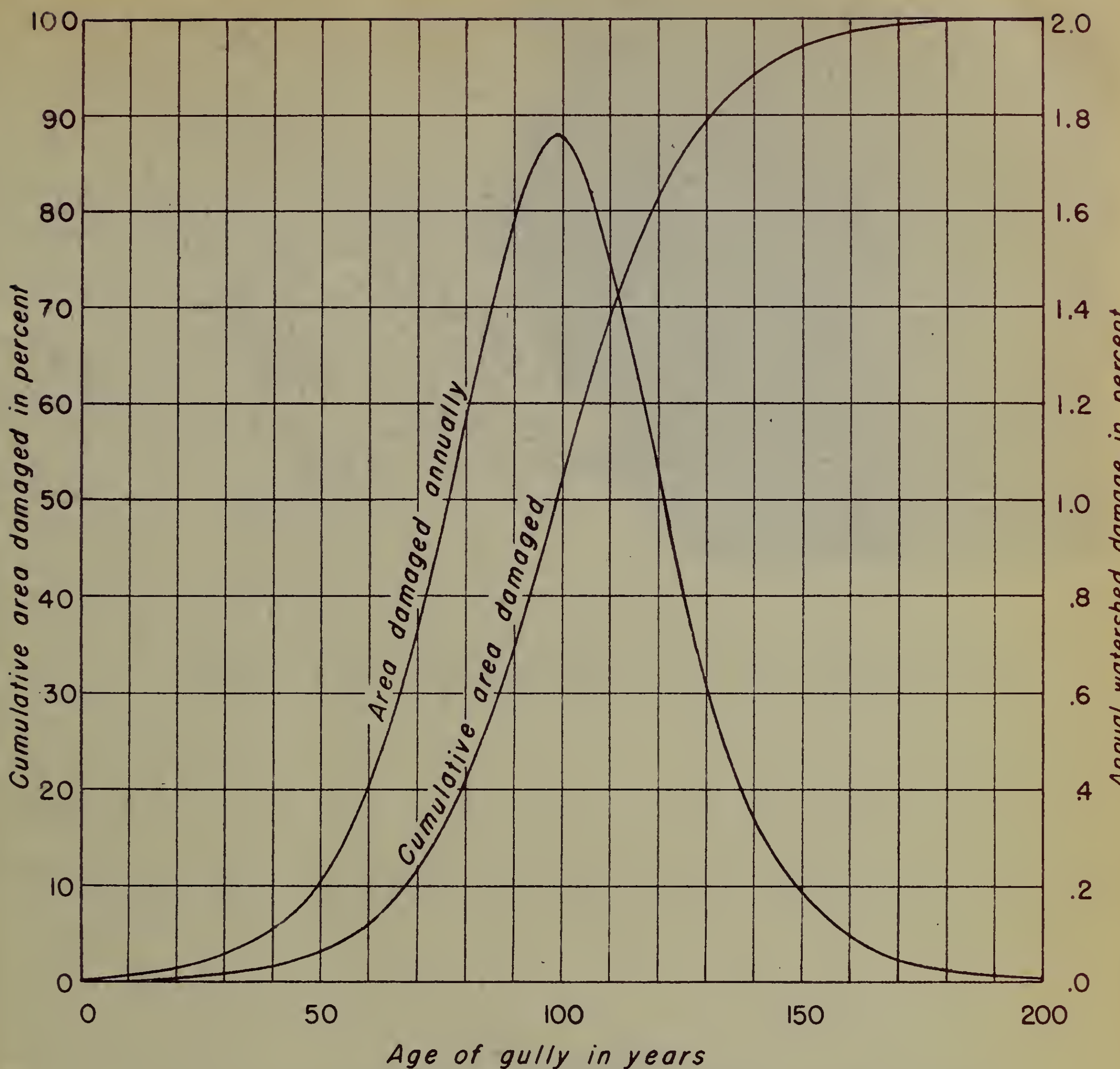
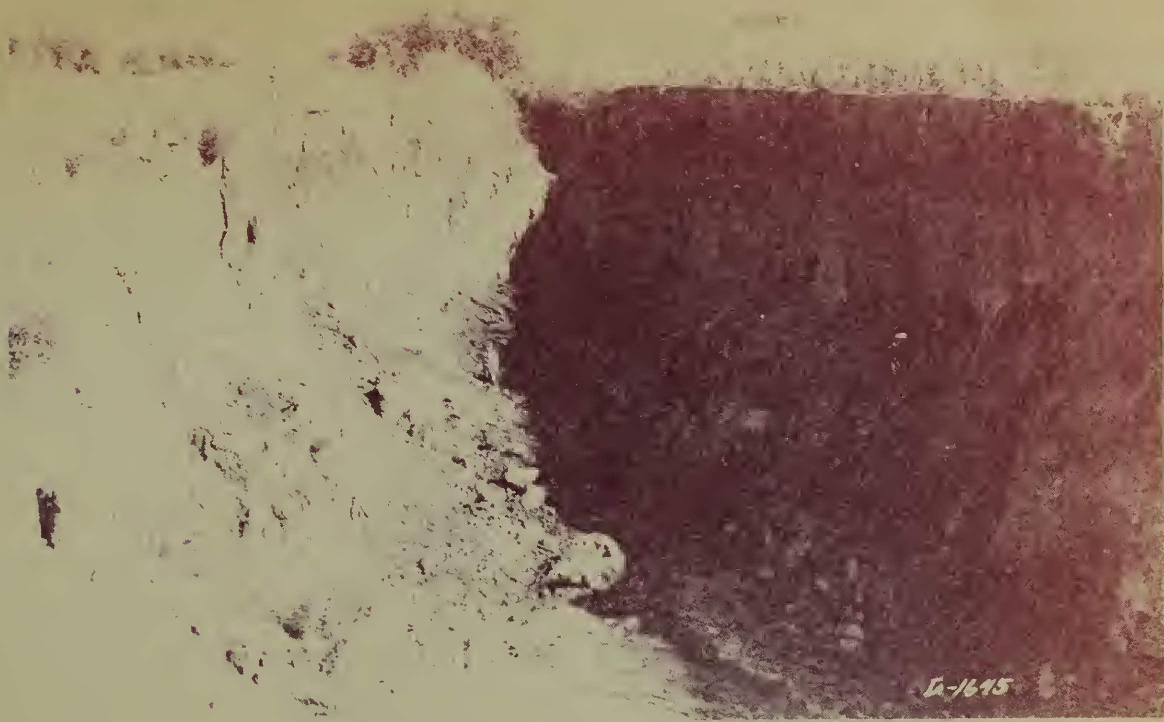


FIGURE 2

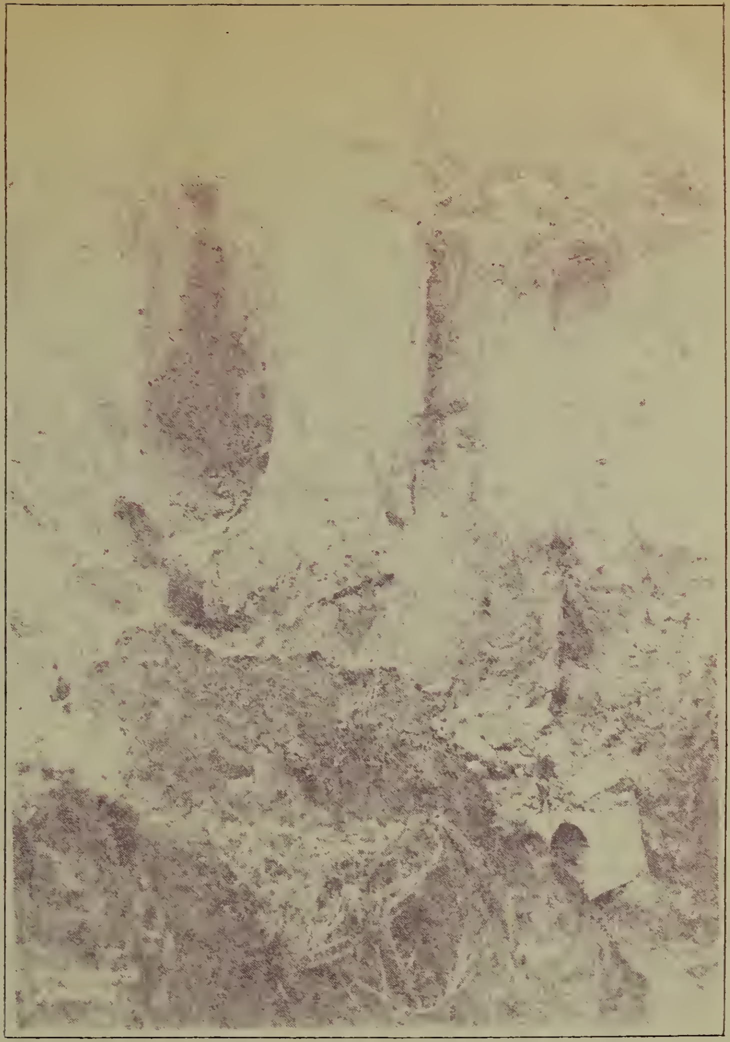
CURVES SHOWING RATE OF DEVELOPMENT OF MAJOR GULLIES

Note: "Area damaged" includes both area destroyed and area depreciated in value.



Typical trench type major gully. Debris from this gully goes directly into Wolf Creek drainage ditch. View looking upstream.

Same gully as shown above. View looking downstream.



Major gully showing destruction to roads and bridges.

Head of major gully in orop land.

As the major gully systems develop, numerous bridges must be constructed and as the gullies are continually enlarging, the cost of maintaining these bridges is unusually large. The cost of both constructing and maintaining these bridges is an additional damage chargeable to the major gullies. However, the difficulty of predicting the number of bridges needed in the future led to abandonment of attempts to evaluate the average annual damage arising from this source.

Flood Damages in Zone 5

Two kinds of damages were evaluated in the Missouri River alluvial plain (Zone 5):

1. Damage to crops and pastures by flood flows exceeding the capacities of the stream channels and drainage ditches.

2. Damage arising from the filling of drainage ditches with sediment that must be removed periodically at great cost.

The damages suffered on the Missouri River alluvial plain were evaluated by the U. S. Engineer Department in the course of an uncompleted flood control survey of the Little Sioux watershed and are subject to modification in the War Department's final report. The apportionment of sediment damages to upland sources was made by the Department of Agriculture by procedures explained in Appendix B. The results of this study of sediment sources led to the apportionment shown by Table 2.

Table 2. Apportionment of Damage to Drainage Ditches

Source of Sediment	Division A	Division B	Total
Sheet and ordinary gully erosion	18,417	14,618	33,035
Major gullies	—	9,058	9,058
Total	18,417	23,676	42,093

Unevaluated Damages

The more important damages not evaluated in terms of money are:

1. Damage to wildlife: Damage to wildlife along the Little Sioux River where fishing and hunting are important forms of recreation is unquestionably high. The major damage is due to the loss of fish and upland game birds resulting from floods and insufficient cover.

2. Interruption of traffic: This is a source of considerable loss. The detouring of traffic around silt and debris filled roads is not uncommon in the late spring and early summer in the lower section of the watershed.

3. Bridge destruction by major gullies: As pointed out previously, the cost of building and maintaining bridges in areas attacked by major gully systems is extremely high.

4. Land destroyed by major gullies: In discussing the damages caused by major gullies it was indicated that only the loss attributable to depreciation in land values was calculated. An additional loss will be sustained when this depreciated land is actually engulfed by the gully and destroyed.

5. Erosion damage aside from that caused by major gullies: Erosion reduces the productivity of the soil and thus does damage that might be expressed in monetary terms. However, erosion also destroys an irreplacable natural resource and no monetary value can be placed upon this loss. For this reason no attempt was made to express erosion damage in terms of money.

Summary of Damages

All of the damages on which monetary values were placed are summarized in Table 1.

Table 1. SUMMARY OF DAMAGES

ANNUAL DAMAGES DETERMINED BY SUBWATERSHEDS

	Subwatershed			
	Little Sioux	Maple River	West Fork	Total
Damages in Zones 2, 3 and 4				
Damage to crops and pastures	105,373	21,170	23,136	149,679
Damage to fences and highways and railroads	27,560	15,224	23,427	66,211
Subtotal				215,890
Damages in Zone 5				
Damage to crops and pastures	15,583	11,481	54,849	81,913

ANNUAL DAMAGES DETERMINED BY DIVISIONS

	Division A	Division B	Total
Damage to land by major gullies	-	205,052	205,052
Damage caused by filling of drainage ditches	18,147	23,676	42,093
Grand Total Average Annual Damages			544,948

SECTION III - CURRENT ACTIVITIES RELATED TO FLOOD CONTROL

Activities of Federal Agencies

War Department

The War Department has been conducting a detailed flood survey of the Little Sioux Watershed. It has made studies to determine the feasibility of detention reservoirs, investigated the possibility of channel improvement work, and studied the feasibility of a flood-way on the Missouri River Flood Plain. These studies indicate that only the last has any possibility of being economically justified. Due to the serious silting that exists at the present time, it is felt that great difficulty would be encountered in maintaining such a flood-way.

Agricultural Adjustment Administration

The Agricultural Adjustment Administration has made payments to farmers for soil building practices throughout the watershed.

Farm Security Administration

The Farm Security Administration has been active in the watershed especially in the rougher areas where, by means of a considerable number of farmers were assisted rehabilitation loans. This agency also has tenant purchase clients scattered throughout the various counties.

Civilian Conservation Corps

The Civilian Conservation Corps operating under the technical direction of the Soil Conservation Service, has been active. In 1941 there were three CCC camps located in or near the Little Sioux Watershed. At that time the camp at Cherokee in Cherokee County had assisted 58 farmers in establishing soil conservation programs on their farms. The camp at Moville in Woodbury County had assisted 72 demonstration farms and the Camp at Moorhead in Monona County, located outside the watershed, had assisted 100 demonstration farms, some of which are in the watershed.

Soil Conservation Service

The Soil Conservation Service in cooperation with the Iowa State Extension Service has assisted 9 demonstration farms in the area. It has served in an advisory capacity to the county agricultural agents in solving local erosion control problems. This agency also affords technical advice and service to Soil Conservation Districts.

Activities of State Agencies

Agricultural Experiment Station and Extension Service

The Iowa Agricultural Experiment Station and Extension Service have been active in the watershed with experimental and educational work.

Activities of Local Agencies

Soil Conservation Districts

Two Soil Conservation Districts have been established in the watershed. They have undertaken to help farmers install Soil Conservation measures

Drainage Districts

There are eight major drainage districts in the Missouri River Alluvial Plain area (Zone 5). In addition to the 8 major districts there are 30 minor districts maintaining lateral ditches.

SECTION IV - THE PROPOSED REMEDIAL PROGRAM

General

After a thorough study of the flood problems of the watershed and of the possible ways of reducing run-off and erosion by treatment of the land, the following remedial programs were designed and their effects on flood damages evaluated:

FOR DIVISION A (Zone 2) - A farmland treatment program under which the Federal government will provide the farmers with plans for using their lands in such a way as to minimize runoff and erosion and will also assist them in installing supplementary measures on the more vulnerable of the lands to remain in intensive use.

FOR DIVISION B (Zones 3 and 4) - Farmland treatment similar to that proposed for Division A in combination with a publicly financed program for the control of gullies so large that they cannot be checked by individual private action.

As the measures required for farmland treatment are similar throughout the area a single description will suffice for both Divisions. It is to be understood, however, that more intensive farmland treatment is required in Division B and thus the cost per unit of area is higher in that Division. The major gully control phase of the program for Division B is separately described.

Farmland Treatment

The plan for farmland treatment was designed to reduce flood runoff and erosion, and at the same time, increase farm incomes; for unless farmers are substantially benefited they cannot be expected to cooperate in the installation and maintenance of the program.

In designing the farmland treatment 157 representative farms were carefully selected in nine areas of a fairly homogeneous character - called "major physical delineations" in this report - and a plan was developed for the proper operation of each of these farms; taking account of its individual capabilities and needs. The effect of the proposed plan upon the income of each farmer was determined to check its practicability and the chances of its being adopted and adhered to for an indefinite period in the future. Details of the farm planning technique are given in Appendix C and the methods used in determining the benefit to the farmer are discussed in Appendix E.

The proposed farmland treatment will reduce flood runoff and erosion by increasing both the amount of storm rainfall taken into the soils and the depth of water that can be temporarily stored on the land surfaces. These effects will be produced by:

1. Increasing the area devoted to protective vegetation such as pasture, grasses, woods and hay, with a consequent decrease in the acreage of clean-tilled crops.

2. Improving the quality of the vegetal covers to increase infiltration and decrease erosion.

3. Minimizing the runoff and erosion from lands remaining in cultivation by use of supplementary measures such as terracing, contour cultivation and soil improvement.

Much of the increase in protective cover will be brought about by the use of crop rotations under which the land will be occupied by close-growing covers a greater percentage of the time. The rotations contemplated vary from a "corn-corn-oats meadow" sequence for the gently slopes of Zone 2, to a rotation of "corn-oats-four years of meadow" for the steeper lands of Zone 4. A further decrease in the acreage of clean tilled crops will be obtained by placing permanent protective covers on slopes too steep for any form of cultivation, using them for pastures or woodlots. During the dormant seasons the area in close-growing vegetation will be increased by the use of winter cover crops.

The program will improve the quality of the protective covers through: The renovation and proper management of pastures; the improvement of woodlots by planting, management and protection against grazing; and the improvement of close growing crops through the increase in fertility brought about by proper rotations. Supplementary measures for improving and preserving the quality of cover on land permanently devoted to grass or trees will include contour furrowing, gully control and waterway protection.

The supplementary measures used to minimize the runoff and erosion from the lands to remain in cultivation will include: Contour cultivation, terracing, waterway protection, gully control, proper use of crop residues and the institution of improved management practices.

Detailed descriptions of the measures mentioned above will be found in Appendix C.

Quantities of Farmland Treatment

Reference to Figure 1 will show that the northern boundary of Zone 2 roughly follows the south and west borders of Clay County and the south boundary of Osceola County. To simplify administration of the program these county lines will be used to designate the upper boundary of the area to be treated. However, much of Zone 1 occurring south of these county lines is land classified in the tables as not requiring treatment.

Table 3 shows the areas of Divisions A and B now devoted to various uses and the areas that would be used for these same purposes if all of the farmers cooperated in the proposed farmland treatment scheme. The increases in the areas of protective covers are apparent and it is largely to these changes that the program owes its effectiveness in reducing runoff and erosion.

Table 3. LAND USE AT PRESENT AND WITH FARMLAND TREATMENT

Assuming all Farmers Participating in Program

Land Use	Division A Present	Division A With Program	Division B Present	Division B With Program	Total Present	Total With Program
Clean Tilled	298,032	227,365	226,731	118,736	524,758	346,098
Small Grain	215,970	119,192	165,214	66,748	381,185	185,941
Rotation-Hay & Pasture	59,705	229,767	74,462	163,728	134,164	393,496
Permanent Hay	24,718	23,949	15,494	75,210	40,213	99,159
Poor Tame Pasture	45,543	2,729	49,645	1,922	95,189	4,651
Good Tame Pasture	61,165	106,268	20,347	133,654	81,513	239,924
Poor Native Pasture	1,863	0	10,306	0	12,171	0
Fair Native Pasture	5	5	3,398	6,890	3,404	6,896
Good Native Pasture	0	0	1,835	7,923	1,835	7,923
Grazed Woodland	7,076	1,382	20,453	3,968	27,529	5,351
Protected Woodland	0	8,605	0	27,538	0	36,141
Unproductive Woodland	0	0	685	701	685	701
Idle Land	4,580	0	17,584	0	22,165	0
Farmsteads	21,674	21,069	16,162	15,298	37,837	36,367
Roads	18,453	18,453	15,316	15,316	33,768	33,768
Total Area to be Treated	758,784	758,784	637,632	637,632	1396416	1396416
Area not Requiring Treatment	195,136	195,136	149,312	149,312	344,448	344,448
Grand Total Area	954,100	954,100	786,944	786,944	1740864	1740864

The quantities of supplementary practices required to permit the recommended uses of the waterhsed lands without continued deterioration are shown in Table 4. These quantities, like those of Table 3, are for 100 percent treatment of the areas included in Divisions A and B.

Table 4

QUANTITIES OF SUPPLEMENTARY SOIL CONSERVATION PRACTICES

Assuming all Farmers Participating in Program

Supplementary Practice	Unit	Division A	Division B	Total
Terracing	Acre	82,495	85,342	167,837
Contour Cultivation	Acre	348,358	212,228	560,586
Contour Furrowing	Acre	476	13,500	13,976
Tree Planting (Gully)	Acre	1,087	6,226	7,313
Tree Planting (Other)	Acre	1,866	5,289	7,155
Gully Control (Minor)	Acre	11,194	8,713	19,907
Gully Control (Medium)	Acre	486	1,001	1,487
Gully Control (Large)	Acre	119	419	538
Fence to be built	Rod	343,036	827,909	1,170,945
Sloping and Sodding	Acre	57	218	275
Diversion Dykes	Feet	112,667	306,683	419,350
Channel Straightening	Feet	422	19,183	19,605
Streambank Protection	Feet	42	7,046	7,088
Earth Dyke	Each	15	179	194

Cost of Farmland Treatment.

The cost of the farmland treatment is made up of:

1. The cost of planning.
2. The cost of installing supplementary measures.
3. The cost of maintenance.

An estimate of the cost of detailed planning was obtained by analyzing the cost accounts of the Soil Conservation Service for work in this and similar areas. It was concluded that planning costs would average $1.38 per acre in Division A and $1.93 in Division B. The entire cost of this planning must be contributed by the Federal government.

Average unit costs for the installation of supplementary measures were also derived from Soil Conservation Service cost accounts. These unit costs were applied against the quantities of Table 4 to obtain the costs shown in Table 5. This table shows the contribution of Federal funds required to insure the installation of the measures, as well as the amounts the farmers would be expected to contribute.

The cost of maintaining the farmland treatment program for any farm is the increase in the cost of operating the farm with the program in effect.

This increase was calculated for each of the sample farms and the data so derived were used to establish an average maintenance cost per unit of area for each of the major physical delineations. These costs were, in turn, employed to estimate the maintenance costs for the entire areas of Divisions A and B.

The estimates of average annual costs developed in the manner above described are shown in Table 6 for the whole of Divisions A and B. These would be the costs if all of the farmers participated in the program. As will be brought out subsequently it is anticipated that only 70 percent of the farmers will cooperate and the final cost estimates used in evaluation were scaled down to this degree of participation.

Table 5.

COSTS OF SUPPLEMENTARY PRACTICES
Assuming All Farmers Participating in Program

	Division A	Division B	Total
Farmer Costs			
Terracing	$ 494,970	$ 512,052	$ 1,007,022
Contour furrowing	952	27,000	27,952
Gully control	89,552	69,704	159,256
Fence to be built	148,945	359,474	508,419
Tree planting	25,191	71,402	96,593
Total Farmer Costs	759,610	1,039,632	1,799,242
Federal Costs			
Gully control	24,050	66,925	90,975
Sloping and sodding	5,130	19,620	24,750
Diversion dykes	5,633	15,334	20,967
Channel straightening	101	4,604	4,705
Streambank protection	42	7,046	7,088
Earth dyke	105	1,253	1,358
Fence to be built	22,573	54,481	77,054
Tree planting (Gully)	19,870	113,812	133,682
Tree planting (Other)	8,920	25,281	34,201
Total Federal Costs	86,424	308,356	394,780
Total Farmer and Federal Costs	$ 846,034	$ 1,347,988	$ 2,194,022

Table 6.

AVERAGE ANNUAL COST OF INSTALLING AND MAINTAINING FARMLAND TREATMENT
Assuming All Farmers Participating in Program

	Federal Contribution	Other Public Contribution	Farmer Contribution	Total
DIVISION A				
Planning and Supervision	36,649	-	-	36,649
Installation (Supplemental Measures)	3,025	-	26,586	29,611
Maintenance	-	-	815,267	815,267
Total	39,674	-	841,853	881,527
DIVISION B				
Planning and Supervision	43,072	-	-	43,072
Installation (Supplemental Measures)	10,793	-	36,387	47,180
Maintenance	-	-	754,367	754,367
Total	53,865	-	790,754	844,619
GRAND TOTAL	93,539	-	1,632,607	1,726,146

The Major Gully Control Program

A major gully, as the term is used in this report, is one that cannot be checked by action of the individual landowners and can only be controlled under a publicly financed program. The structures required to stop the devastation of farm lands by such gullies are large and expensive. A study of 29 sample gullied drainage areas led to the conclusion that, in general, the most economical control could be obtained by the installation of large earth dams at strategic points in the main gullies and the construction of numerous flumes and other conveying devices for lowering the water into the gully system without producing additional cutting. About half of the dams could replace bridges now being maintained over the gullies at great cost.

Quantities

The study of the 29 representative gully systems led to the following estimate of the number of structures required to control the major gullies.

Table 7 NUMBER OF STRUCTURES REQUIRED TO CONTROL MAJOR GULLIES

Dams on main gullies	371
Dams on lateral gullies	73
Structures for conveying water into gullies	447
Total number of structures 1/	891

Cost of Major Gully Work

The cost of installing the major gully control program was determined by: (a) Estimating the cost of the structures required on the sample gullied watersheds; (b) determining the cost per unit of area for the zones represented by these samples, and; (c) applying these unit costs against the total areas of the sampling zones. In estimating the cost of the larger structures average unit costs were applied against the quantities of material, excavation and fill required. The cost of the smaller structures was estimated by applying an average cost per structure against the number of structures required. The unit costs used were derived from an analysis of cost accounts for similar types of work elsewhere.

The cost of maintenance provides for inspection, repair and replacement of structures expected to fail under unusual conditions. It is sufficient, therefore, to maintain the program in perpetuity.

The estimated costs of the major gully program are summarized in Table 8.

1/ All of these structures to be constructed in Division B. The number of structures required were estimated by determining quantities required per unit area of samples and multiplying by areas of zones represented by these samples.

Table 8

COST ESTIMATES
MAJOR GULLY CONTROL

Installation Costs

Item	Number of Structures	Cost of Installation (Dollars)
Dams on main gullies	371	1,960,337 1/
Dams on lateral gullies	73	173,156
Structures for conveying water	447	281,430
		2,414,923
Plus 15% for contingencies, etc.		362,239
Total Installation Cost		2,777,162
Average Annual Installation Cost		97,200

Maintenance Costs 2/
(Average Annual)

Inspection	2,600
Repair	6,200
Replacement	11,200
Total Average Annual Maintenance	20,000

1/ The cost of earth fills for these dams amounts to $736,821. Half of this cost, or $368,410, is to be contributed by local public agency or agencies.

2/ Costs of operation, repair and replacement to be contributed by local public agency or agencies.

SUMMARY OF COSTS FOR 70 PERCENT PARTICIPATION

The estimates given in the foregoing represent the cost of installing a program on all farms requiring treatment in Divisions A and B. It is expected that only 70 percent of the farmers will cooperate in the farmland treatment phase of the program but that the entire major gully control program will be installed. The average annual costs of this program are shown in Table 9.

Table 9. COSTS OF INSTALLATION AND MAINTENANCE
For Farmland Treatment on 70 Percent of Area
And Complete Treatment of Major Gullies.
AVERAGE ANNUAL COSTS

Watershed Division	Federal	Other Public	Farmer	Total
		Installation and Maintenance		
DIVISION A				
Farmland Treatment	27,772	-	589,297	617,069
DIVISION B				
Farmland Treatment	37,705	-	553,528	591,233
Major GullyControl	84,306	32,894	-	117,200
Totals for Division B.	122,011	32,894	553,528	708,433
Total Average Annual Costs	149,783	32,894	1,142,825	1,325,502
		TOTAL INSTALLATION COSTS		
DIVISION A				
Farmland Treatment	793,482	-	531,727	1,325,209
DIVISION B				
Farmland Treatment	1,077,290	-	727,742	1,805,032
Major Gully Control	2,408,752	368,410	-	2,777,162
Total for DivisionB.	3,486,042	368,410	727,742	4,582,194
Total Installation Costs	4,279,524	368,410	1,259,469	5,907,403
		AVERAGE ANNUAL MAINTENANCE COSTS		
DIVISION A				
Farmland Treatment	-	-	570,687	570,687
DIVISION B				
Farmland Treatment	-	-	528,057	528,057
Major Gully Control	-	20,000	-	20,000
Total for DivisionB	-	20,000	528,057	548,057
Total Average Annual Maintenance Costs	-	20,000	1,098,744	1,118,744

SECTION V - PHYSICAL EFFECTS OF THE PROGRAM

To determine the monetary benefits produced by the proposed remedial measures it is necessary to know the physical effect they still have upon: (a) flood runoff; (b) the area and duration of inundation; (c) erosion from the land, and; (d) the productivity of the land. The methods used in estimating these effects are briefly described in the following and more fully treated in Appendix D. The conversion of the physical effects to monetary benefits is explained in Section VI.

Effect on Flood Run-off

The effect of farmland treatment upon flood run-off was determined by calculating the amount of storm rainfall that would be infiltrated into the soil with the land it its present condition and the infiltration that would occur after installation of the remedial program. The increase in infiltration is the reduction in surface flood run-off. Moreover, since the soil mantle of this watershed is of great depth and has practically unlimited storage capacity, the effect of subsurface run-off upon flood flows can be neglected and the reduction in surface runoff can be taken as the reduction in flood runoff.

To determine the effect of the remedial treatment upon infiltration representative sites were selected in each of the more important complexes of soil, cover and condition or cultural practice existing in the watershed. Artificial rainfall was then applied to small plots established at these sites. By measuring the rate of application of rainfall to these plots, and the rates of run-off from them, the rates of infiltration were determined and infiltration curves derived. For selected storms these curves were used to calculate the total amount of infiltration and run-off for each complex. This made it possible to compute the total volume of run-off from any watershed by simply multiplying the areas of the complexes present, or anticipated under the program, by the run-off from these complexes. The difference between the calculated run-off with and without the program in effect represents the reduction in flood volume.

To convert the reduction in flood volume to reductions in peak discharge a curve showing the average relation between flood volume and peak flow was developed for each watershed used in evaluation. By use of these curves the flood volumes for conditions both without and with a program were converted to peak flood discharges.

As mentioned in Section II it was found possible to develop an evaluation series for both the Little Sioux and Maple rivers from stream gaging records. For these streams therefore it was decided to develop only the average reductions in flood discharges and to apply these average reductions against each flood in the present evaluation flood series to obtain an evaluation series for conditions with a program. The average flood reductions were obtained by calculating the reduction in the floods that would be caused by six derived storms of average characteristics. The intensity of rainfall in these six storms followed an average pattern developed from a study of the Sioux City, Iowa, recording rain gage records.

For each storm the surface run-off was calculated for conditions both without and with a program. These calculations were made for all portions of the watershed contributing to the stream reaches used in calculating flood damage. Curves showing the reduction in peak flow at the lower end of each reach were then constructed and used in the derivation of the evaluation series for treated conditions.

As gaging records were not available for use in developing an evaluation series for the smaller subwatersheds the infiltration curves were used to compute series of floods that might be expected on these watersheds without and with the program in effect. This was accomplished by assuming that all of the rains recorded by the Sioux City, Iowa, automatic gage during a 16 year period of normal rainfall characteristics, could have occurred at some central point in the West Fork (proper) and Elliott Creek watersheds. The intensities during each large storm in this period were determined by five minute periods and used in conjunction with the infiltration curves to calculate surface run-off. The total run-off for each storm was determined by methods similar to those employed in deriving the run-off for the six average storms used for the Little Sioux and Maple Rivers.

To illustrate the magnitude of the flood reductions calculated by the foregoing procedure the curves of Figure 3 have been prepared. These curves show the percentage reduction in peak discharge at the points where the streams discharge upon the Missouri River alluvial plain. The curves for the Little Sioux and Maple rivers are those developed for the six average storms. The curves for the West Fork and Elliott Creek represent the approximate averages of the reductions for the 37 individual floods in the evaluation series for these watersheds.

Detailed explanations of the methods used in calculating the flood run-off will be found in Appendix D.

Effect on Area and Duration of Inundation

The effect of the proposed remedial treatment upon the area inundated by any flood was obtained by hydraulic calculations. Using the results of these calculations, curves showing the area inundated in each damage reach were derived (see Appendix D). These curves were used in developing the "damage-flood magnitude" curves mentioned in Section II and shown in Appendix B. They were also used in determining the percentage reduction in area inundated by which the fence, highway and railroad damages were multiplied to estimate the benefits derived through reducing these damages. The Areas inundated by each flood in both the present and future evaluation series are shown in Appendix D. The percentage reductions in the sums of the areas inundated are given in Table 10.

Estimates of the time that flood waters remained on various parts of the flood plain were required in deriving the damage-flood magnitude curves. These were made by use of hydrographs of average shape, which were in turn employed to construct special diagrams (see Appendix D) showing the duration of inundation at key points along the stream. Estimates of reductions in duration of inundation were not required for individual floods because they are reflected in the damage-flood magnitude curves

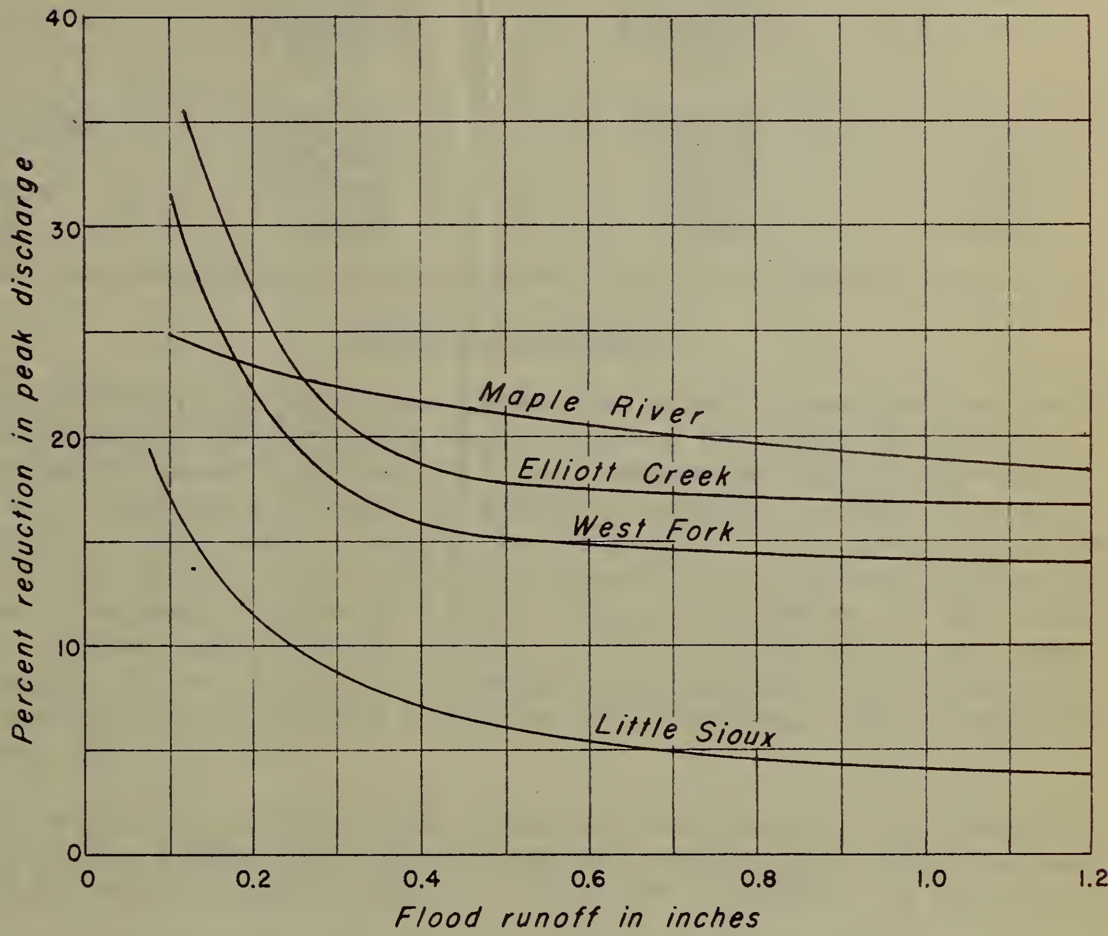


FIGURE 3

AVERAGE FLOOD REDUCTIONS

THAT WOULD RESULT FROM THE INSTALLATION

OF THE PROPOSED PROGRAM ON ALL FARMS

Shown For Illustrative Purposes Only

Note: Reductions are for points at which streams enter the Missouri River alluvial plain.

Table 10 EFFECT OF FARMLAND TREATMENT PROGRAM IN REDUCING AREAS INUNDATED 1/

Stream	Sum of Areas Inundated by 2/ All Floods in Evaluation Series		Percentage Reduction
	Without Treatment Acres	With Treatment Acres	
Little Sioux 3/	312,421	281,962	9.75
Maple	116,915	73,196	37.5
West Fork	50,355	38,028	24.5
Elliott	11,622	8,527	26.5

Effects on Erosion

The effect of farmland treatment upon erosion from the land surfaces was determined by assigning to each cover and treatment a relative erosion factor based upon research data secured at Soil Conservation Experiment Stations and upon the survey of erosion in this watershed. These factors were used to weight the area under each cover and treatment, in each of the major physical delineations, with and without the farmland treatment program in effect. Having estimates of the erosion for both present and treated conditions by delineations, it was possible to calculate the erosion for the whole of Divisions A and B and from these results the percentage reduction by Divisions. These reductions are shown in Table 11.

In evaluating the benefits accruing from the control of the major gullies it was assumed that after they are treated they will discharge only 10 percent as much material as they now contribute to the streams.

Table 11. EFFECT OF FARMLAND TREATMENT UPON EROSION 1/

Division	Reduction in Erosion - Percent
A	49.6
B	65.2

1/ This table shows the effect of farmland treatment upon all erosion except that attributable to the major gullies.

1/ Effect of treatment assuming all farms cooperating. In calculating benefits these reductions were multiplied by .70 to approximate reduction for 70 percent participation.

2/ Does not include inundation in Missouri River alluvial plain.

3/ For that part of Little Sioux in Zones 2, 3 and 4.

Effect on the Productivity of the Land

To make possible an evaluation of the "on-site" benefits, or benefits accruing to the landowners, it was necessary to determine the effect of the farmland treatment program upon the yields of crops, pastures and woodlots throughout the area surveyed. The methods used in arriving at these estimates are explained in Appendix D and the estimates themselves are there presented in some detail. In general it was found that in 30 years the remedial program will increase corn yields about 40 percent over those now obtained, but that if present methods of farming are continued yields will have decreased about 20 percent at the end of the 30-year period. In the same period pasture yields would be roughly doubled under the program while with continuation of present practices a reduction of about 10 percent can be expected. Effects intermediate between those for corn and pasture were found for oats and hay. The specific yield increases found for each physical delineation were used in developing farm budgets for the sample farms used in the program design and in this way the on-site monetary benefits of Section VI were estimated.

SECTION VI - BENEFITS OF THE PROGRAM

Calculation of Benefits

Benefits on the Missouri River alluvial plain (Zone 5) were evaluated separately from those in the remainder of the surveyed area (Zones 2, 3 and 4). In the latter area the items of benefit evaluated were:

1. Benefits derived by reducing damages to crops and pastures.
2. Benefits derived by reducing damages to fences, highways and railroads.
3. Benefits derived by reduction in damage to land by gullies.

The evaluated benefits for the Missouri River alluvial plain were:

1. Benefits derived by reducing damages to crops and pastures.
2. Benefits derived by reducing rate of filling of drainage ditches.

An estimate was also made of the on-site benefits; that is, the benefits accruing to the landowners. The methods used in evaluating each of these types of benefit are briefly described below. A more detailed discussion will be found in Appendix E.

Benefits From Reducing Crop and Pasture Damages in Zones 2, 3 and 4

By the procedures described in Section V the floods in the evaluation series for present conditions were converted to floods that would be experienced after the proposed program became effective. The damage that would be caused by each flood in these modified series was then calculated and the average annual damages for conditions with a program determined. The differences between the present and future average annual damages thus derived were taken as the average annual benefits. These benefits are derived in Appendix E for a program in which all of the farmers would participate. To obtain the benefits for the anticipated 70 percent participation these benefits were simply multiplied by 0.7.

Benefits from Reducing Fence, Highway and Railroad Damage in Zones 2, 3 & 4.

The average annual benefits derived by reducing damages to fences, highways and railroads were estimated by applying the percentage reductions in the sums of the areas inundated against the damages shown in Section II. These reductions in area inundated are shown by Table 10. The benefits for the main stems were derived by applying the actual percentage reduction calculated for each subwatershed main stem. For minor tributaries it was assumed that the reduction in area would be the same as for Elliott Creek - the smallest of the streams for which a calculation was made - and the 26.5 percent reduction for this stream was applied against all minor stream damages. In the case of crop and pasture damages, the benefits thus derived were reduced by 30 percent for the expected 70 percent participation.

Benefits From Controlling Major Gullies

The major gully control works were designed to completely halt the progress of these gullies. However, to insure conservative estimates it was assumed that the benefits would only be 90 percent of the land damages given in Section II. Attention should again be called to the fact that only the losses attributable to land depreciation were included in these damages and that the large additional damages that would come about through complete destruction of the depreciated land and through the necessity of building and maintaining numerous bridges, were not counted among the monetary benefits.

Benefits From Reducing Crop and Pasture Damage in Zone 5

The reduction in crop and pasture damages on the Missouri River alluvial plain were estimated by applying to the damages now experienced the relative reduction in the number of floods that would exceed the capacities of the ditches after the remedial program is put into effect. These benefits are calculated in Appendix E for a program in which all farmers would participate. Assuming that only 70 percent of the farmers would actually enter the program the benefits so determined were arbitrarily reduced by 30 percent.

Benefits From Reducing Rate of Ditch Filling

As explained in Section V reductions in upland erosion were calculated for Divisions A and B. These reduction factors were applied against the damages apportioned to these areas in Section II to arrive at an estimate of the benefits that would accrue through reducing the cost of maintaining the drainage ditches. However, the full effect of the program will not be felt immediately as a moderate amount of sediment will be in transit at the time it is installed. In calculating the benefits claimed, therefore, it was assumed that the annual benefits would increase uniformly through a ten year period and remain constant thereafter. The present value of this series of annual benefits was taken as the total benefit and this was reduced to the average annual equivalent given in Table 14.

On-Site Benefits

The on-site benefits were calculated by determining the amount that future farm income on the sample farms would exceed present income if the program were installed. This yielded a conservative estimate of benefits in that it is expected that farm incomes will decrease in the future if present methods of farming are continued. The details of these calculations are given in Appendix E.

Calculation of Benefits by Divisions

As previously pointed out the three major subwatershed used in calculating flood reduction benefits did not include the entire areas of Divisions A and B. To estimate the benefits that would be produced by treatment of the entire area within a Division it was necessary, therefor to apply appropriate benefits per unit area to the area not lying within these subwatersheds.

Unevaluated Benefits

The proposed program will produce substantial benefits that have not been claimed in the report. It will ameliorate the present damages to wildlife, reduce the number of interruptions to traffic, eliminate the cost of providing and maintaining numerous bridges in the areas attacked by major gullies, and forestall the complete destruction of depreciated lands adjacent to the gully system. Some benefit will no doubt be realized from the reduction of the contribution of silt to the Missouri River. It will also minimize the erosion losses now being suffered on upland farms. This latter effect is of tremendous importance, as the preservation of the soil resource for the use of future generations is a social obligation of the highest order.

Summary of Monetary Benefits

The benefits derived by the methods outlined above are summarized in Tables 13, 14 and 15. Table 13 gives, for the subwatersheds, the benefits accruing to the farmland treatment by reason of the effect it has on flood and related damages. Table 14 gives the average annual benefits by Divisions. Table 15 shows the on-site benefits in Divisions A and B.

From these tables it will be seen that the benefits claimed for the reduction of flood and related damages total $253,979. The farmland treatment phase of the program produces about 25 percent of this total and the remaining 75 percent results from the control of major gullies.

Table 13

Reductions in Damages by Floods to Crops, Pastures, Fences, Highways and Railroads by Subwatersheds For Farmland Treatment on 70 Percent of Area

Type of Damage Reduced to Produce Benefit	Benefit in Dollars
LITTLE SIOUX	
Above Zone 5	
Crop and pasture	10,284
Fence, highway and railroad	4,700
Total above Zone 5	14,984
In Zone 5	
Crop and pasture	575
MAPLE RIVER	
Above Zone 5	
Crop and pasture	5,594
Fence, highway and railroad	2,865
Total above Zone 5	8,459
In Zone 5	
Crop and pasture	3,444
WEST FORK	
Above Zone 5	
Crop and pasture	2,964
Fence, highway and railroad	4,313
Total above Zone 5	7,277
In Zone 5	
Crop and pasture	13,273

Table 14

FLOOD AND RELATED BENEFITS ATTRIBUTABLE
TO TREATMENT OF DIVISIONS A AND B
(For Farmland Treatment on 70 Percent of Area
and Complete Treatment of Major Gullies)

Source of Benefit	Average Annual Benefit in Dollars Division A	Division B
Farmland Treatment		
Reduction in crop, pasture, fence, highway and railroad damage attributable to the treatment of:		
Little Sioux subwatershed	$ 11,657	$ 4,590
Maple River subwatershed	5,987	5,916
West Fork subwatershed	8,568	11,982
Minor tributary watersheds 1/		2,470
Reduction in rates of ditch filling	5,504	5,743
Major Gully Control		
Reduction in land damage		184,546
Reduction in rates of ditch filling		7,016
Total	$ 31,716	$ 222,263

1/ Small tributaries not draining into any of the three main tributaries. Benefit derived by applying average benefit per unit area for Division B.

Table 15

ON-SITE BENEFITS PRODUCED BY FARMLAND TREATMENT
70 Percent of Area

Division	Average Annual On-site Benefits
A	$1,485,893
B	1,141,397
Total	$2,627,290

SECTION VII - COMPARISON OF BENEFITS AND COSTS

The benefits that would be produced by the proposed remedial program are compared with costs in Table 16. An examination of this table will show:

1. That the expenditure of each dollar of public funds will produce flood benefits amounting to 1.14 dollars in Division A and 1.43 dollars in Division B.

2. That the farmers will profit by cooperating in the program as in Division A they will receive 2.52 dollars for each dollar they invest and in Division B, 2.06 dollars.

3. That the total benefits exceed the total costs for both Divisions of the area treated; in Division A the return on each dollar being 2.46 dollars and in Division B, 1.92 dollars.

Table 16

BENEFITS AND COSTS
Of Farmland Treatment on 70 Percent of Area
And Complete Treatment of Major Gullies

	DIVISION A	DIVISION B
BENEFITS 1/		
Flood Control	$ 31,716	$ 222,263
On-site	1,485,893	1,141,397
Total	$1,517,609	$1,363,660
COSTS 2/		
Federal	$ 27,772	$ 122,011
Other Public		32,894
Farmer	589,297	553,528
Total Contribution	$ 617,069	$ 708,433
Flood Control Benefits per Dollar Federal Cost	1.14	1.82
Total Benefits per Dollar Total Cost	2.46	1.92

1/ Average annual benefits from Table 14

2/ Average annual costs from Table 9

APPENDIX A

WATERSHED DESCRIPTION AND BASIC PHYSICAL DATA

CONTENTS

SECTION I - DESCRIPTION OF WATERSHED

Location: The Little Sioux watershed is located in northwestern Iowa and southwestern Minnesota. The river rises in Jackson county, Minnesota and flows 200 miles in a southwesterly direction to River Sioux, Harrison County, Iowa, where it empties into the Missouri River. It has a total drainage area of 4,502 square miles and the source is 590 feet in elevation above the mouth. The average gradient of the stream is 2.67 feet per mile. The basin is 135 miles long and is relatively narrow. Its maximum width is 50 miles at a point about 50 miles above its mouth.

The gradient of the river through the Missouri River Flood Plain portion is less than one foot per mile. The elevation is 1,010 feet above mean sea level at the Missouri River.

There are three major streams in the watershed. They are West Fork, the main stem of the Little Sioux, and the Maple River. All of these streams are independent of each other until they reach the Missouri River Flood Plain. The confluence of the Maple and the Little Sioux occurs just below the town of Turin where the Maple reaches the Missouri River Flood Plain. The West Fork empties into the Little Sioux about 1/8 mile above the confluence of the Little Sioux and the Missouri River. However, there is an equalizer ditch between the Little Sioux and West Fork about 10 miles above the mouth of the Little Sioux.

Physical Description: The watershed is divided into 6 general topographic areas. (See Figure A-1). Zone 0 is the irregular terminal moraine area developed by the Wisconsin glacier. Zone 1 is the level area covered by the Wisconsin glacier and lies just south of Zone 0. Zone 2 is a gently rolling area, the surface of which is predominantly of loessial origin. Zone 3 is a steeply rolling area also of loessial origin where slopes of 8 to 15 percent predominate. Zone 4 is a bluff area of loessial soil where rough topography exists and slopes are predominantly 15 to 50 percent. Zone 5 is the alluvial flood plain of the Missouri River. At the present time, this area is not flooded by the Missouri River.

The soils of the watershed are, in general, very productive. Limited areas of poorly drained bottomland exist in the Missouri River Flood Plain portion of the area. The use of open drainage has relieved this problem materially and much of this land is now used for wheat production. In the glacial drift area of the watershed, most of the land has been tiled. Otherwise, no significant drainage problems have existed. In all but the steep bluff area of Zone 4, agricultural crops are used on the land. Timber is not a source of livelihood in the bluff area but it exists on the north and east slopes of the bluffs where the use of agricultural crops has not been found feasible.

Population: The total population of this watershed in 1930, as estimated from data for townships which are 50 percent or more within the basin, was 125,900 persons. This represents a population density of approximately 28 persons per square mile. There were only three towns with a population of more than 2,500 persons; Cherokee in Cherokee County with 6,443; Spencer in Clay County with 5,019; and Worthington in Nobles County, Minnesota with 3,878. This gives a total urban population of 15,340 or 12 percent of the total. In addition there are several small villages.

The farm population in 1930 (including 102 urban-farms) was 70,630, or 56.1 percent of the total population. This represents a farm population density for the entire area of 15.5 persons per square mile. The farm population as estimated from data obtained from the 1935 census of agriculture is 68,334.

Land Tenure: Corporate ownership of land is fairly extensive in Zones 1 and 3. Most of such land is held by insurance companies or banks which became owners through foreclosure.

In 1934, 65.5 percent of all farm land in the watershed was rented. This proportion varied from 63 percent to 72.5 percent. Only two townships had less than 45 percent of their farm land operated by tenants, while several had 75 percent so operated. Absentee ownership is considerable.

Land Cover: According to the 1935 census report, 96.0 percent of the watershed was in farms. In 1934, 71.9 percent of the farm land was in crop land and 65.0 percent was in harvested crops. The moderately eroded area (Zone 2) had the highest proportion of the land in harvested crops and in total crop land. The bottomland area (Zone 5) had a high percentage of crop land, but about one-third of the crop land was reported as crop failure, idle or fallow land in 1934.

Land Management: Many farmers do not consider soil erosion to be a serious problem, although cultivation of many fields and parts of fields has been abandoned because of it. While much of the top soil has been removed from the rolling land, most farmers believe crop yields have not decreased materially. Crop yields average higher on the loess soils of Zones 2 and 3 than on other parts of the watershed.

Very few farms have adapted their farm practices to the prevention of erosion and reduction of run-off. In 1934 corn occupied 48.6 percent of the acreage in harvested crops. In the seriously eroded Zone 3 the percentage of harvested crops in corn was approximately 58 percent. The highest proportion of crop land in corn was in the townships with large amounts of bottomland, while the lowest proportion was on the more level upland in the central (Zone 2) and northern (Zone 0) parts of the watershed.

Pastures generally are over-grazed. Contour farming and engineering structures for erosion prevention are rare.

Farm Economy: Nearly all the farms in the watershed are of commercial types with very few self-sufficing farms or part-time farms. Livestock farms predominate throughout the area with cash grain farms second in importance. Grain farms are most frequent in the bottomland of Zone 5 and on the relatively level glacial soils of Zone 1. Beef cattle and hogs are fed in large numbers in all parts of the watershed. In 1935 the census reported an average of 37 swine and 28 cattle per farm.

The average size of farms is about 200 acres, with relatively little variation between the different parts of the watershed in this respect, except that the average in the bottomland area (Zone 5) is 217 acres per

farm. In all parts of the watershed corn is by far the most important crop. In Zones 0, 1, and 5 some of it is sold as a cash crop, while in Zones 3 and 4 nearly all of it is fed.

In 1929, the average value of farm products sold, traded or used by the farm family was $4,077 per farm. The average for the State of Iowa was $3,303. Gross incomes per acre were $19 in Zones 1 and 2 and $25 in Zones 3 and 4. The gross value of products, however, does not present an accurate picture of differences in net incomes because of the variation in expenses, particularly for the purchase of feeder cattle.

Variations in the value of land and buildings per acre reflect in part, the variations in net incomes. In 1935, the average value per acre of farms in the entire watershed was $78. The average for the State of Iowa was $72. Land values are lowest in the southern part where the predominant soils are either bottomland types, which are subject to overflow and poor drainage, or steeply rolling upland types, which are subject to serious erosion and excessive run-off.

In 1934, the average cash rent per acre for the counties in the watershed was $5.74. During the same year the average for the State of Iowa was $4.88. The average for the counties on the more level land in the northern part of the watershed was $5.61, as compared to $6.00 on the gently rolling loess soils and $5.46 on the more rolling loess soils.

Mortgage indebtedness of owner-operated farms in the watershed amounted to about 50 percent of their value in 1930. There was not a great deal of variation among counties. This is about equal to the average for the State of Iowa. The amount of indebtedness has been reduced since 1930, but the fixed charges that farmers and landlords must pay on mortgages continues to be an important factor in the encouragement of an exploitive type of farming.

In 1935, the farm real estate tax was about $1.00 per acre. Delinquency of taxes on farm real estate was not a serious problem prior to 1929. Before that year the accumulated delinquency was less than 10 percent of the current levy in all counties within the watershed. Accumulated delinquent taxes increased rapidly during the period 1929 to 1933 and in 1933 reached a peak of 32 percent of the current levy in Zones 0 and 1, 23 percent in Zone 2, and 35 percent in Zones 3 and 4. In more recent years, however, delinquencies have declined.

SECTION II - SOILS OF THE WATERSHED

The characteristics of the soils of the watershed are summarized in Table A-1.

TABLE A-1. SOILS OF THE LITTLE SIOUX WATERSHED

	Marshall silt loam	Marshall silt loam (brown phase)	Knox silt loam	Hamburg very fine sandy loam	Hamburg very fine sandy loam (valley phase)	Ute silt loam
Origin	Loess	Loess	Loess	Loess	Accumulation at base of Hamburg catsteps	Accumulation at base of steep Knox slopes
Native vegetation	Prairie	Prairie	Mixture, some grasses, sumac, scrub oak	Little blue-stem	Little blue-stem	Tall blue-stem
Topography	Gently undulating to gently rolling	Rolling to rough	Strongly rolling	Steep catsteps	12-18% slopes	12-18% slopes
Profile Character-istics	0-12"-very dark grayish brown silt loam. 12-20"-dark grayish brown to yellowish brown silt loam. 20-30"-yellowish brown heavy silt loam. Below 30"-pale yellowish brown to grayish yellow silty clay loam.	0-8"-grayish brown silt loam. 8-15"-light brown heavy silt loam. 15-24"-pale yellow silt loam. Below 24"-pale yellow to grayish yellow silty loam.	0-7"-grayish brown silt loam. 7-16"-light brown to buff silt loam. 16-34"-light yellowish brown to grayish yellow silt loam.	0-4"-gray very fine sandy loam containing some organic matter. Below 4"-grayish yellow very fine sandy loam, loose, friable, no development.	0-14-20"-yellowish gray very fine sandy loam. Below 20"-grayish yellow very fine sandy loam, loose, friable, no development.	0-14-20" grayish brown loam. 20-34" grayish yellow silt loam. Below 34" - pale yellow or light grayish yellow floury silt loam.
Surface drainage	Good	Good	Good	Good	Good	Good
Internal drainage	Good	Good	Good	Good	Good	Good
Productivity	High	Medium high	Medium low	Very low	Medium high	Medium high
Surface soil reaction	Slightly acid	Slightly acid to neutral	Medium to basic	Calcareous	Calcareous	Neutral to Calcareous

(continued on next page)

TABLE A-1. (continued - sheet 2)

	Marcus silty clay loam	Afton silty clay loam	Pierce fine sandy loam	Dickinson fine sandy loam	Clarion fine sandy loam	Clarion loam (steep phase)
Origin	Loess	Loess	Wisconsin drift	Wisconsin drift	Wisconsin drift	Wisconsin drift
Native vegetation	Prairie	Prairie	Prairie	Prairie	Prairie	Sparse timber
Topography	Level to flat	Level to depressed	Rolling to rough	Gently to strongly rolling	Gently rolling to rolling	Rolling to rough
Profile character-istics	0-18"-very dark grayish brown silty clay loam. 18-28"-brown to grayish brown silty clay loam. 28-36"-yellowish brown silty clay loam mottled with gray and brown Below 36"-pale yellowish brown silty clay loam mottled with gray and yellow.	0-15"-black silty clay loam. 15-26"-gray or drab heavy silty clay loam. 26-36"-gray or drab silty clay mottled with gray drab and brown. Below 36"-light gray silty clay lightly mottled with yellow gray. drab and brown.	0-8"-dark brown fine sandy loam. 8-16"-brown to yellowish brown loamy fine sand to sand. Below 16"-light gray sand and gravel, highly calcareous.	0-12"-dark grayish brown fine sandy loam. 12-25"-brown to yellowish brown loamy fine sand to sand. 25-40"-yellowish brown to yellow fine sand. Below 40"-yellow gravelly sand	0-10"-dark grayish brown to dark brown fine sandy loam. 10-15"-yellowish brown fine sandy loam. 15-23"-yellowish brown to light brown sandy clay loam. 23-32"-yellowish brown sandy clay loam.	0-7"-dark brown fine sandy loam. 7-20"-yellowish brown clay loam mottled with brown. Below 20"-yellowish brown to yellow silty clay loam.
Surface drainage	Poor unless supplemented artificially.	Deficient	Good	Good	Good	Good
Internal drainage	Moderate	Moderate	Good to excessive	Good to excessive	Good	Good
Productivity	High	High	Moderately low	Moderately low	Moderately low	Moderate
Surface soil reaction	Medium acidity	Medium to low acidity	Slightly acid	Medium to high acidity	Medium to low acidity	Neutral

TABLE A-1. (continued - sheet 3)

	Clarion loam	Clarion silt loam	Webster silty clay loam	Sioux loam *	Waukesha silt loam	Judson silt loam
Origin	Wisconsin drift	Wisconsin glacier	Wisconsin glacier	Glacial outwash terrace	Terrace	Terrace
Native vegetation	Prairie	Prairie	Grasses	Grasses	Grasses	Grasses
Topography	Level to slightly undulating	Gently rolling to rolling	Level to flat or depressed	Level to gently undulating	Near level	Level to gently undulating
Profile characteristics	0-16"-very dark grayish brown to brown loam. 16-21"-yellowish brown to yellow silty clay streaked with gray. Below 30"-grayish yellow or yellow sandy clay or clay loam mottled with gray, yellow and brown.	0-17"-very dark grayish brown to dark brown silt loam. 17-24"-brown to yellowish brown silty clay loam. 24-34"-yellowish brown to yellow heavy silty clay loam. Below 34"-grayish yellow or yellow sandy clay mottled with gray, yellow and brown.	0-10"-very dark grayish brown to black silty loam. 10-15" dark grayish brown heavy silt loam. 15-24"-dark brown to brown silty clay. 24-33"-dark gray or drab silty clay. Below 33"-gray, gritty, silty clay highly mottled with yellow and brown.	0-18"-dark grayish brown to brown heavy loam. 18-24"-light brown to yellowish brown loam. 24-33"-yellowish brown to brown fine sand to sand and gravel. Below 33"-stratified coarse sand and gravel.	0-18"-dark grayish brown to brown heavy loam. 18-24"-brown to yellowish brown silty clay loam. 24-32"-light yellowish brown to yellow heavy silty clay loam. Below 32"-yellow silty clay mottled with gray and brown.	0-16"-very dark grayish brown silt loam. 16-28" light brown to heavy silt loam to silty clay loam. 28-36"-light silty clay loam. Below 36"-brown silty clay loam mottled with gray, yellow and gray.
Surface drainage	Good	Good	Poor	Good	Good	Good
Internal drainage	Good	Good	Slightly restricted	Excessive	Good	Good
Productivity	High	High	High	High unless droughty	High	High
Surface soil reaction	Medium to low acidity	Medium to low acidity	Low acidity to slightly basic	Low acidity	Medium acid	Medium acid

* Also similar to O'Neill loam, another major terrace type, except that the latter type is acid in the surface.

TABLE A-1. (continued - sheet 4)

	Wabash silt loam	Lamoure silty clay loam
Origin	Recent alluvium from loessial and silty glacial soils.	Recent alluvium from streams draining calcareous soils.
Native vegetation	Grasses and trees	Grasses and trees
Topography	Level to depressed	Level to depressed
Profile characteristics	0-14"-black silt loam. 14-25"-dark to grayish brown or drab heavy silt loam. 25-34"-dark gray to drab silty clay loam to clay mottled with yellow and brown. Below 34"-light gray silty clay to mottled with yellow and brown clay.	0-13"-black silty clay loam. 13-23"-dark drab to grayish brown silty clay loam. 23-36"-brownish gray to gray silty clay to clay mottled with gray, yellow and brown. Below 36"-gray or drab silty clay mottled with yellow and brown.
Surface drainage	Moderately poor in general	Moderately poor in general
Internal drainage	Restricted	Restricted
Productivity	High when well drained and protected from overflow	High when well drained and protected from overflow
Surface soil reaction	Medium acid	Basic


LITTLE SIOUX WATERSHED
JACKSON
NOBLES
ZONE 0
OSCEOLA
DICKINSON
EMMET
ZONE 1
O'BRIEN
CLAY
PALO ALTO
ZONE 2
CHEROKEE
BUENA VISTA
PLYMOUTH
ZONE 3
IDA
SAC
WOODBURY
ZONE 4
ZONE 5
MONONA
CRAWFORD
HARRISON
LEGEND
RECONNAISSANCE SOIL CONSERVATION SURVEY
ZONES

SECTION III - SUB-DIVISION OF THE WATERSHED INTO DELINEATIONS AND ZONES

For use in designing a remedial program and in evaluating its effects upon flood run-off and erosion the lands of the watershed were sub-divided into "physical delineations" or areas having a fairly homogeneous pattern of soil, slope, erosion and land-use. The delineations mapped are shown by Figure A-1. The areas of the delineations finally selected for design and evaluation purposes are summarized by subwatersheds in Table A-2.

To determine the composition of the delineations and also to secure the economic data needed in determining the effect of the program upon farm incomes, sample farms were selected at random in each of the nine most important delineations. The number of farms studied in each delineation is shown in Table A-2a. In all 157 farms were investigated. The portion of the watershed covered by the terminal moraine was not sampled as it had previously been determined that it would be excluded from the area surveyed. Bottomland delineations were also omitted.

It was found that for some purposes an even broader classification than the physical delineations would be helpful. Accordingly the six "zones" of Figure A-2 were outlined. The principal differences between these zones is in their topography; the slopes becoming progressively steeper proceeding downstream.

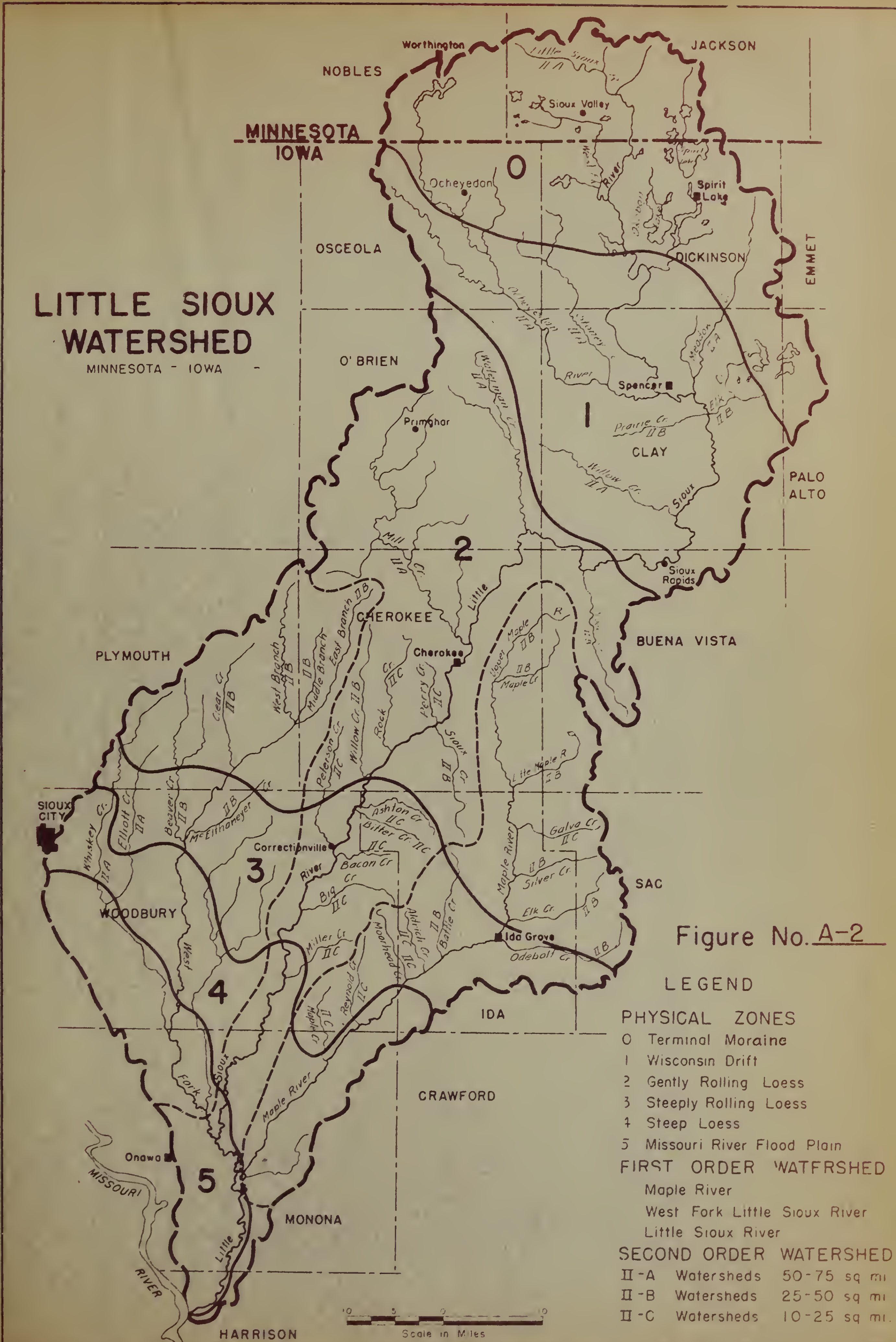


Figure No. A-2

L-3019

TABLE A-2. MAJOR PHYSICAL DELINEATIONS (square miles)

Tributary	Square Miles																	
	26 1/ A +	9 B 1	9 B 2	9 C 2&3	11 C 2	11 C 3	11 D 1	11 D 2	11 D 3	150 C&D 1&2	9 A 1	74 A 1	107 113 0&1	138 B 1	138 B 2	227 A 1	258 A 0	Total 2/
Little Sioux	151.8	314.1	250.5	90.3	13.7	23.3	.6	6.7	22.9	167.9	20.8	6.5	22.7	9.6	21.7	38.4	.2	1161.7
Maple	138.1	110.1	231.7	92.1	23.8	60.0	7.6	21.3	47.8	7.5								740.0
West Fork	107.5	88.4	210.3	28.6	45.3	138.2	7.7	83.7	107.1	.9								817.7
Mo. Flood Plain	303.2																	303.2
Total	700.6	512.6	692.5	211.0	82.8	221.5	15.9	111.7	177.8	176.3	20.8	6.5	22.7	9.6	21.7	38.4	.2	3022.6

1/ Upper figure denotes soil type, middle figure the slope, and lower figure the erosion condition.

2/ This total includes not only the upland but also the bottomland and roads for which no remedial land use program was planned. The unit area of roads is found in the summaries of the delineations in Appendix B, Section 1.

TABLE A-2a. NUMBER OF SAMPLE FARMS STUDIED IN THE VARIOUS DELINEATIONS OF THE LITTLE SIOUX WATERSHED

Delineation	Random Farms	SCS contract Farms	Total
9-B-1	10	4	14
9-B-2	16	3	19
9-C-2 & 3	16	4	20
11-C-2	16	1	17
11-C-3	20	4	24
11-D-1	9	0	9
11-D-2	17	1	18
11-D-3	22	1	23
150-C & D	13	0	13
Total	139	18	157

TABLE A-3. DISTRIBUTION OF LAND IN MAJOR DELINEATIONS BY SOIL TYPE AND EROSION CLASS

Major Delineation & Soil Type	Percent of Area by Erosion Classes 1/								Total Percen
	+	+ 7	-7V	1	2	22	3	6	
Delineation 11-D-2									
S.T. 12				.71					.71
" 150							.65		.65
" 9					1.21	.50			1.71
" 11				7.19	8.04	11.88	16.17	21.00	64.28
" 257				.25	2.61	4.11	8.14		15.11
" 26a	3.29	11.22	3.03						17.54
	3.29	11.22	3.03	8.15	11.86	16.49	24.96	21.00	100.00
Delineation 11-D-3									
S.T. 11				1.97	7.29	5.16	23.51	1.72	39.65
" 257				.07	2.41	12.52	24.57		39.57
" 26a	2.69	6.33	10.03	.72	.58		.43		20.78
	2.69	6.33	10.03	2.76	10.28	17.68	48.51	1.72	100.00
Delineation 9-B-1									
S.T. 9				4.73	44.92	27.55	2.98		80.18
" 227	0.45			4.12	2.38				6.95
" 138-169				1.24	3.80	1.34			6.38
" 26-26a-48-107	4.03	2.13	0.33						6.49
	4.48	2.13	0.33	10.09	51.10	28.89	2.98		100.00
Delineation 11-C-3									
S.T. 9				.50	3.12	3.60	1.12		8.34
" 11				.30	.35	2.01	20.72	.29	23.67
" 257					2.49	14.70	33.63		50.82
" 26a	5.21	5.23	6.73						17.17
	5.21	5.23	6.73	.80	5.96	20.31	55.47	.29	100.00
Delineation 9-B-2									
S.T. 9				5.82	24.19	37.62	.87	.92	69.42
" 138					1.16	.72	.18		2.06
" 169					3.03	1.87			4.90
" 11					.33	.30	1.71		2.34
" 257						.83	3.04	.05	3.92
" 75-131	.26			1.28	.58	.25			2.37
" 107-26-26a-48	8.36	3.20	3.31					.12	14.99
	8.62	3.20	3.31	7.10	29.29	41.59	5.80	1.09	100.00

(continued on next page)

TABLE A-3. (continued)

Major Delineation & Soil Type	Percent of Area by Erosion Classes 1/								Total Percent
	+	+ 7	+7V	1	2	22	3	6	
Delineation 11-C-2									
S.T. 9				1.28	3.34	1.66	1.34		7.62
" 11				.09	.56	4.47	27.44	.19	32.75
" 257					1.22	14.00	29.53		44.75
" 26a	4.16	6.39	4.33						14.88
	4.16	6.39	4.33	1.37	5.12	20.13	58.31	.19	100.00
Delineation 11-D-1									
S.T. 9									
" 11				18.31	18.63	5.36	8.36	29.68	80.34
" 257				.08	3.28		2.34		5.70
" 26a	1.31	2.69	9.96						13.96
	1.31	2.69	9.96	18.39	21.91	5.36	10.70	29.68	100.00
Delineation 150-C & D-1 & 2									
S.T. 9-169				2.59	10.09	14.99	2.60		30.27
" 151				1.45	4.20	11.48	7.03		24.16
" 138				.26	7.83	7.97	.15		16.21
" 75				3.01	1.23				4.24
" 11				.96	2.04	5.57	1.24	.30	10.11
" 26a	7.86	4.17	2.98						15.01
	7.86	4.17	2.98	8.27	25.39	40.01	11.02	.30	100.00
Delineation 9-C-2 & 3									
S.T. 9				1.05	18.36	41.36	6.25	.04	67.06
" 257						9.55	4.67		14.22
" 138					1.28	2.55	.95		4.78
" 26a	2.66	1.95	8.67	.66					13.94
	2.66	1.95	8.67	1.71	19.64	53.46	11.87	.04	100.00

1/ For meaning of erosion class symbols, see Figure A-1.

TABLE A-4. TOTAL SOIL LOSS (IN ACRE FEET PER SQUARE MILE) BY DELINEATIONS (MAJOR) IN THE LITTLE SIOUX WATERSHED.

Major physical Delineation	Sheet Erosion	Gully Erosion	Total
9-B-1	276.0	2.8	278.8
9-B-2	274.0	3.7	277.7
9-C-2 & 3	309.0	4.8	313.8
11-C-2	256.0	4.7	260.7
11-C-3	251.0	7.4	258.4
11-D-1	99.0	1.7	100.7
11-D-2	128.0	3.5	131.5
11-D-3	250.0	7.2	257.2
150-C & D-1 & 2	244.0	.6	244.6
26-A- -	Bottomland		

SECTION IV - SOIL EROSION

Estimates of the rate at which soil is being eroded from various parts of the watershed were derived from detailed erosion surveys on the sample farms. To obtain an estimate of the soil previously lost through accelerated erosion the depths of topsoil were determined on virgin areas and it was assumed that on like soils and slopes any reductions in these virgin depths were attributable to cultivation. Soil losses attributable to small gullies were determined by measuring the gullies on the sample farms.

From the erosion surveys of the sample farms the average distribution of degrees of erosion was derived for each physical delineation and are shown by Table A-3. These average distributions were converted to actual soil loss by assigning the following average losses to each class of sheet erosion:

Class Symbol	Percent of Topsoil Lost	Average loss in Percent
1	0- 25	18.75
2	25- 50	37.50
22	50- 75	62.50
3	75-100	87.50

The resulting estimates of the amounts of soil that have been eroded from each physical delineation are given in Table A-4.

To obtain an estimate of the amount of soil removed by the major gullies in the lower part of the basin measurements were made of sample gullies. These samples were classified by size into three groups and for each group the volume of material removed was determined. These determinations were made for each of the important physical delineations. The resulting estimates of volume are shown in Table A-5.

Table A-5. VOLUME OF SOIL REMOVED BY MAJOR GULLIES

Physical Delineation	Acre Feet of Material per Square Mile
11-C-2	49.7
11-C-3	40.5
11-0-1	99.4
11-0-2	95.8
11-0-3	192.8

SECTION V - SOURCES OF SEDIMENT REACHING DRAINAGE DISTRICTS

To determine the source of the sediment deposited in the drainage ditches on the Missouri River alluvial plain it was not only necessary to estimate the erosion from the land, but also to determine what portion of the eroded material actually finds its way into these ditches. This required a determination of the amount of eroded material deposited upstream from the Missouri River alluvial plain. The procedure used is briefly outlined in the following.

Definition and Description of Problem Areas

Watershed Divisions: First order watersheds - The entire Little Sioux Watershed can be subdivided into three major first order watersheds; the Little Sioux, Maple River and West Fork subwatersheds previously discussed.

Second order watersheds - The second order watersheds are tributary to the first order streams and to the Missouri River flood plain area (See Figure A-2). These units are complete watersheds smaller in size than the first order. Table A-7 lists these. They vary in size from ten to one hundred square miles and can be divided into the three following classes.

Class II - A watersheds - These are watersheds ranging in size from 50 to 75 square miles.

Class II - B watersheds - This group includes watersheds ranging in size from 25 to 50 square miles.

Class II - C watersheds - These watersheds range in size between 10 and 25 square miles.

Third order watersheds - These watersheds vary in size from one to ten square miles. They are tributary to the first order streams, second order streams and to the open Missouri River flood plain area. The sediment in these watershed units occurs on small tributary bottoms and in traps above fences and roads.

The third order watersheds were further subdivided into 40-acre units based on their position within the small watershed (See Figure A-3). Three classes of 40-acre units were established. They were:

Unit 1 (See Figure A-3)—These units are located on the main stream of the third order watersheds and usually have the greatest volume of sediment of any three units.

Unit 2 (See Figure A-3)—These units are located in an intermediate position between the main stream of the third order watersheds and the watershed divide. These are in reality fourth order watersheds. In these units there is a moderate sediment accumulation on small bottoms.

Unit 3 (See Figure A-3)—These units are located on the watershed divides. Erosion is prevalent in these units, however, sediment

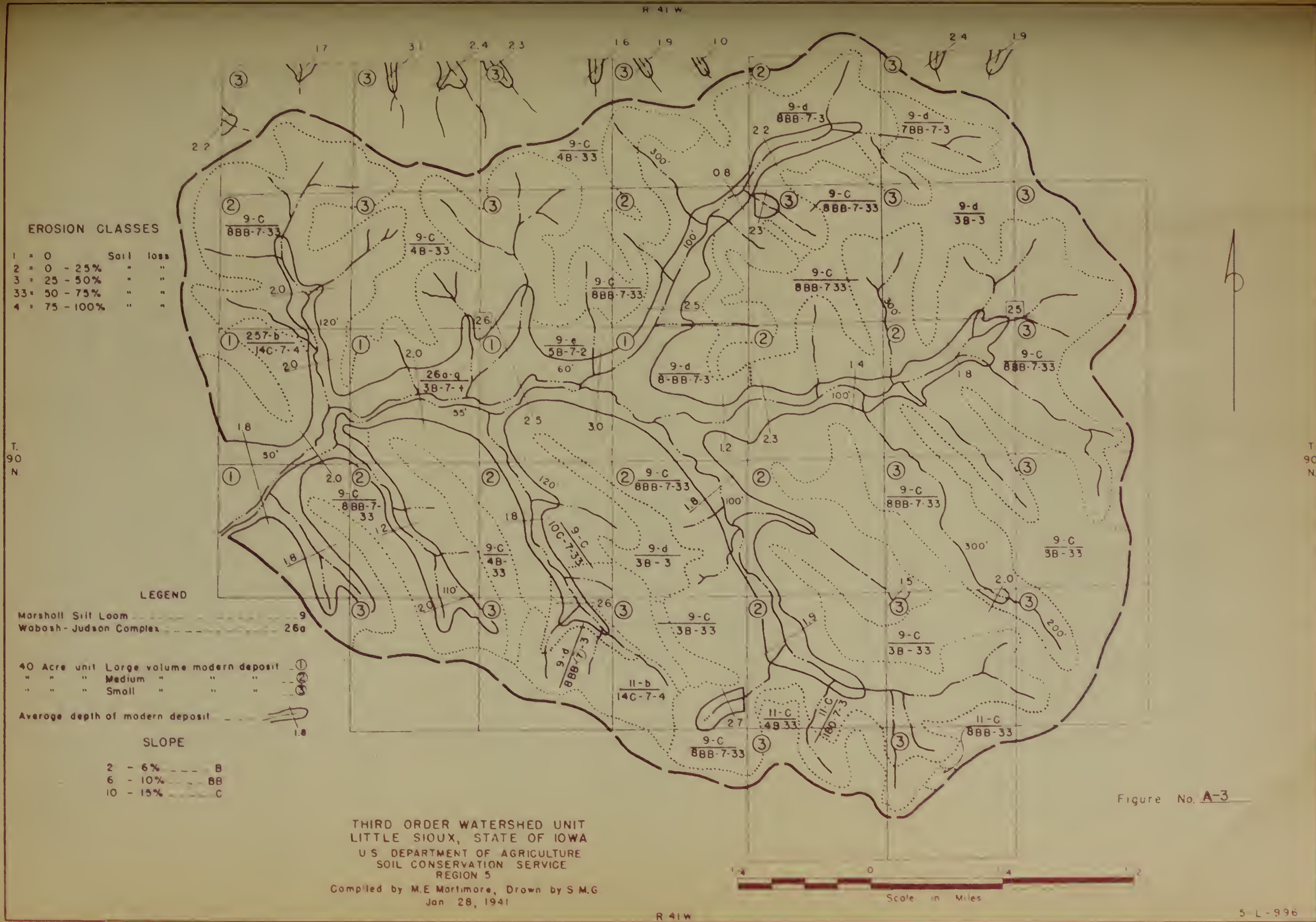

R 41 W
T. 90 N.
EROSION CLASSES
1 = 0 Soil loss
2 = 0 - 25% " "
3 = 25 - 50% " "
33 = 50 - 75% " "
4 = 75 - 100% " "
LEGEND
Marshall Silt Loam 9
Wabash - Judson Complex 26a
40 Acre unit Large volume modern deposit 1
" " " Medium " " " 2
" " " Small " " " 3
Average depth of modern deposit 1.8
SLOPE
2 - 6% B
6 - 10% BB
10 - 15% C
THIRD ORDER WATERSHED UNIT
LITTLE SIOUX, STATE OF IOWA
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
REGION 5
Compiled by M.E. Mortimore, Drawn by S.M.G.
Jan 28, 1941
Scale in Miles
5 L-996

Figure No. A-3

accumulation is found in traps above fences and roads. These units are a number of small watersheds which could be termed fifth order watersheds.

Physical Zones: The units in this classification are the generalized zones referred to in Section I. These zones are based on a broad grouping of the soil, slope and erosion delineations shown on the reconnaissance conservation survey map. This classification made possible the grouping of second order watersheds in order to have a systematic basis for the selection of sample units for valley sedimentation surveys. It also formed a natural division of the first order valleys into reaches. For the location of these zones see Figure A-2.

Major Physical Delineations: The divisions delineated on the reconnaissance conservation map were used as a basis for the selection of farm samples on which the volume of sediment in third order watersheds was determined.

Measurement of Deposition

Deposits in Valley Segments: The volume of modern deposit on the main bottoms of the first and second order watersheds was secured on valley segments at regular intervals one-half mile in length and three to six miles apart.

The area of sedimentation was delineated on aerial photographs in each segment. Sediment depth was determined by borings along range for each segment. The volume of sediment in acre-feet for each segment was computed from these areas and depth of deposits expanded to a reach of the valley half-way to the adjacent segments.

The volume of modern deposits in the form of alluvial fans on high terraces was determined on each valley segment. The area of deposit was delineated on aerial photographs and the average depth was determined by boring parallel ranges 400 to 600 feet apart across these areas. The volume in acre-feet per valley mile was computed and expanded to the portion of the valley half-way to the adjacent segments.

The second order watersheds were classified further in relation to their position in each of the physical zones. Sample segments were selected in relation to these various classes.

Deposition in the third order valleys: The deposits in third order watersheds occur along small stream valleys and in traps above fences and roads (See Figure A-3). The average depth of sediment in each small valley was secured along range lines at intervals of approximately 1500 feet (See Figure A-3). The average depth of modern deposit in the small areas, trapped above fences and roads, was determined by borings along a line across the middle of the area. The average depth of deposit in all cases was a weighted average along the range lines.

These areas of sediment deposit were delineated on the detailed conservation maps, in the manner illustrated by Figure A-4, for each 40-acre unit of sample farms. The volume of deposit in acre-feet was computed from these areas.

These sample farms were each given a number on the upper center part of the map (See Figure A-4). Each of these farms was divided into 40-acre units. The average depth of soil in feet and the area in acres is indicated on the margin of the map. Also opposite each unit there is an equation which is as follows:

$$\frac{\text{III-9}}{\text{C - 3}} \quad \text{or} \quad \frac{\text{40-acre Unit Class - Soil Type}}{\text{Slope - Erosion Class}}$$

The soil type, slope and erosion corresponds to those on the reconnaissance conservation survey map. The number of the 40-acre unit is indicated at the left of the equation, as $2 - \frac{\text{III-9}}{\text{C - 3}}$. The volume of sediment in acre-feet is shown at the right of the equation as $2 - \frac{\text{III-9}}{\text{C - 3}}$ 1.1 acre-feet.

The volume of sediment was then compiled in the manner illustrated by Table A-7. To make it possible to check back to the farm map from these tables, the farm numbers and 40-acre unit numbers were inserted just above each sediment volume figure and underscored. The volume of sediment for each physical delineation in these units was computed and recorded in Table A-8.

It was determined that the number of these units within a given third order watershed have a uniform ratio as follows:

Unit 1	Unit 2	Unit 3
1	2	4

To determine the volume of upland deposits per square mile in each physical delineation these units were expanded in proportion to the above ratios. These figures resulted in total deposition in acre-feet per square mile per delineation per third order watershed. In other studies (land use, hydrologic, soils) it was found that differences between some of the delineations were not significant. In light of this, some of the delineations were grouped. The third order deposition units were also grouped in order that uniformity would exist. After grouping the delineations, the third order deposition per delineation, in acre-feet per square mile, became as follows:

9-B-1	=	71.7 acre-feet per square mile
9-B-2	=	80.0 " " " " "
9-C-2 & 3	=	138.1 " " " " "
11-C-2	=	123.5 " " " " "
11-C-3	=	134.4 " " " " "
11-D-1	=	40.0 " " " " "
11-D-2	=	98.1 " " " " "
11-D-3	=	122.1 " " " " "
150-C-D & 1-2	=	140.0 " " " " "

Erosion less third order deposition is shown in Table A-9. This table shows the volume of deposit passing from the third order watersheds to the larger streams.

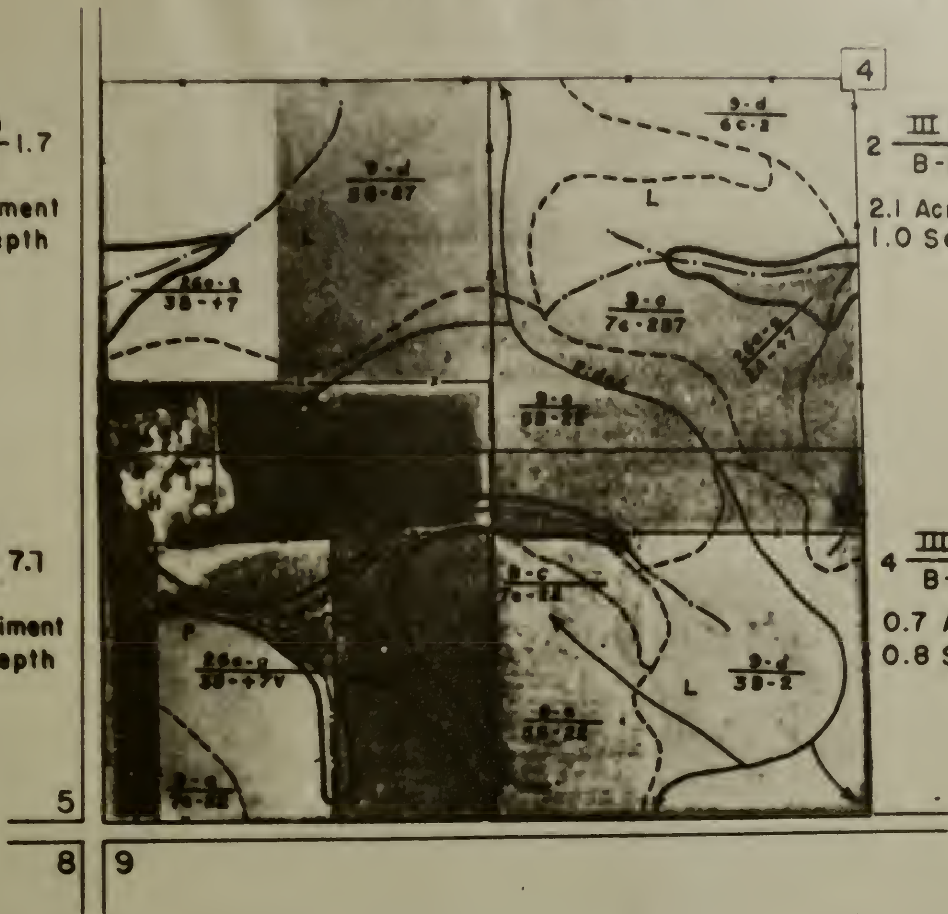
FARM NO. 82

$1 \frac{\mathrm{III}\ 9}{\mathrm{B}\ 2} 1.7$

1.4 Acres of Sediment
1.2 Sediment Depth

$2 \frac{\mathrm{III}\ 9}{\mathrm{B-2}} 2.1$

2.1 Acres of Sediment
1.0 Sediment Depth



$3 \frac{\mathrm{II}\ 9}{\mathrm{B}\ 2} 7.1$

9.6 Acres of Sediment
0.8 Sediment Depth

$4 \frac{\mathrm{III}\ 9}{\mathrm{B-2}} 0.6$

0.7 Acres of Sediment
0.8 Sediment Depth

Figure No. A-4

NOTE: LEGEND ATTACHED

SOIL TYPES		SLOPE	
SYMBOL	NAME	SYMBOL	PERCENT
9	Marshall silt loam	A	0-2
26a	Wabash-Judson silt loam	B	2-6
		C	6-12
		D	12-18
		E	18-over

LAND USE CAPABILITY LEGEND

I	II	III	IV	V

CONSERVATION SURVEY MAP

LITTLE SI'UX FLOOD CONTROL, CHEROKEE, IOWA

AGREEMENT NO.

OWNER B. J. Clausseen
ADDRESS Ida County
OPERATOR LeRoy Madsen
ADDRESS Ida Co., Logan Twp.
SCALE 8" : 1 mile ACRES 160.0
LEGAL DESCRIPTION SW¼ S4 Ida Co.
T. 88 N., R. 40 W.

AERIAL INDEX NO. BKD-3-38

TABLE A-6. II ORDER WATERSHEDS

Creek Name	Tributary to	Sub Class	Physical Zones
Little Whiskey	Open Plain	B	4
Big Whiskey	"	A	2-3-4
Wolf	"	A	2-3-4
Elliott	"	A	2-3-4
Miller	Little Sioux River	C	3
Big	" "	C	3
Bacon	" "	C	3
Bitter	" "	C	3
Ashton	" "	C	3
Peterson	" "	C	2-3
Willow (Lower)	" "	B	2-3
Rock	" "	C	2-3
Mapleton	Maple River	C	3
Reynolds	"	C	3
Moorehead	"	C	3
Aldrich	"	C	3
Battle	"	B	2-3
Odebolt	"	B	2-3
Elk	"	B	2-3
Silver	"	B	2
Galva	"	C	2
Little Maple	"	B	2
Pitcher	"	C	2
Maple	"	B	2
Upper Maple	"	B	2
West Branch	West Fork Little Sioux	B	2
Middle Branch	" " "	B	2
East Branch	" " "	B	2
Beaver	" " "	B	2-3
McElthaney	" " "	B	2-3
Clear	" " "	B	2-3
Mill	Little Sioux River	A	2
Waterman	" "	A	2
Brook	" "	B	2
Willow (Upper)	" "	A	1
Elk	" "	B	1
Prairie	" "	B	1
Meadow	" "	A	0-1
Ocheyedan	" "	A	0-1
Stony	" "	A	0-1
Upper Little Sioux	" "	A	0-1

TABLE A-7. *SUMMARY OF THIRD ORDER SEDIMENT DEPOSITION (in acre-feet) BY 40-ACRE UNITS FOR MAJOR DELINEATIONS INVOLVING SOIL GROUP 9

Physical Unit of 3rd Order Watershed															
I	I	I	I	I	II	II	II	II	II	III	III	III	III	III	III
Slope and erosion of major physical delineation															
B1	B2	B3	C2	C3	B1	B2	B3	C2	C3	B1	B2	B3	C2	C3	C3
	7-3 / 7.3	3-2 / 18.7	79-7 / 17.3	50-14 / 26.0	5-1 / 6.8	1-4 / 4.0	3-1 / 4.1	18-2 / 10.8	1-2 / 21.8	4-1 / 8.4	1-1 / 0.2	3-3 / 2.3	18-1 / 1.7	2-1 / 3.4	50-32 / 0.0
	7-4 / 9.3	14-1 / 24.9		50-15 / 38.8	5-4 / 6.6	44-2 / 10.3		18-5 / 10.5	8-3 / 12.0	4-2 / 4.0	1-2 / 1.7	3-4 / 2.5	18-3 / 3.2	2-3 / 0.7	50-33 / 0.0
	53-4 / 21.9	14-3 / 14.9		50-16 / 58.2	16-2 / 8.8	81-1 / 6.8		18-6 / 5.6	9-1 / 5.1	4-3 / 1.5	1-3 / 3.8	14-2 / 3.9	18-4 / 0.0	2-4 / 8.0	50-34 / 0.0
	83-1 / 18.2	14-4 / 13.3		50-17 / 44.9	66-1 / 3.5	81-2 / 3.4		79-1 / 12.1	9-2 / 26.6	4-4 / 2.7	7-1 / 1.1		79-2 / 1.2	8-1 / 3.6	68-4 / 0.0
		81-6 / 7.8		72-2 / 37.5	66-4 / 18.7	81-3 / 9.1		79-5 / 10.7	9-5 / 8.3	5-2 / 0.2	7-2 / 2.1		79-3 / 4.1	8-2 / 3.4	72-1 / 0.0
						81-5 / 6.6		84-4 / 11.1	9-4 / 8.6	5-3 / 1.4	50-26 / 0.0		79-4 / 4.8	8-4 / 3.4	82-2 / 1.1
						82-3 / 7.7		84-3 / 9.2	50-10 / 11.5	5-5 / 1.9	50-32 / 0.0		79-6 / 0.9	50-1 / 3.0	86-1 / 3.6
									50.11 / 4.0	5-6 / 1.3	22-1 / 2.5		84-1 / 0.9	50-2 / 12.1	86-2 / 3.6
									50.18 / 19.2	6-1 / 4.4	22-2 / 1.6		84.2 / 0.0	50.3 / 3.6	86-3 / 1.4
									50.19 / 15.3	6-2 / 8.3	22-3 / 2.3		84-5 / 11.5	50-5 / 13.2	
									50-21 / 4.8	6-3 / 8.1	22-4 / 8.6			50-6 / 1.7	

(continued on next page)

TABLE A-7. (continued)

Physical Unit of 3rd Order Watershed															
I	I	I	I	I	II	II	II	II	II	III	III	III	III	III	III
Slope and erosion of major physical delineation															
B1	B2	B3	C2	C3	B1	B2	B3	C2	C3	B1	B2	B3	C2	C3	C3
									50-22 / 13.5	6-4 / 0.7	44-1 / 0.0			50-7 / 11.3	
									50-23 / 16.9	6-5 / 2.8	53-1 / 2.1			50-8 / 0.4	
									50-24 / 8.4	6-6 / 0.0	53-2 / 0.8			50-12 / 0.0	
									50-30 / 16.9	16-1 / 7.2	52-3 / 1.9			50-13 / 0.0	
										16-3 / 1.8	81-4 / 0.8			50-20 / 0.0	
										16-4 / 1.9	81-7 / 1.8			50-26 / 0.0	
										66-2 / 7.4	81-8 / 4.8				50-27 / 2.0
										66-3 / 0.4	82-1 / 1.7				50-29 / 8.0
											82-2 / 2.1				50-31 / 0.0
											82-4 / 0.6				
											83-2 / 0.0				
Total	56.7	79.3	17.3	205.4	44.4	47.9	4.1	70.0	192.9	64.4	40.5	8.7	28.3		97.1
Average	14.2	15.8	17.3	41.0	8.0	6.8	4.1	10.0	12.8	3.4	1.8	2.9	2.8		2.9

* Legend $\frac{7\text{-}3}{7.3}$ is $\frac{\text{Farm number- 40-acre unit number}}{\text{Deposition in acre-feet for the 40-acre unit.}}$

TABLE A-8. AVERAGE DEPOSIT IN ACRE-FEET 3rd ORDER WATERSHEDS FROM CONSERVATION SURVEY MAP 40 ACRE UNITS

I			II			III			
9 Marshall	257 Marshall	11 Knox	9 Marshall	257 Marshall	11 Knox	9 Marshall	257 Marshall	11 Knox	
			8.9			3.4			B1
14.2			6.8			1.8			B2
15.8			4.1			2.9			B3
								2.6	C1
17.3	26.6	21.6	10.0	8.7	10.5	2.8	3.2	2.6	C2
35.2	26.4	23.8	12.8	10.6	11.4	2.9	3.1	3.0	C3
					9.8				D1
		18.7			10.1			1.0	D2
	27.8	27.0		9.3	8.6		2.9	2.3	D3
								1.5	DD1
									DD2
		17.2			6.6			3.6	DD3

Determination of Sediment Reaching Drainage Districts: By subtracting the third order deposition from the estimated erosion derived in Section IV of this Appendix the delivery of sediment to the second order streams is determined. The deliveries from each physical delineation is shown by Table A-9. These values were used to estimate the total delivery of sediment to second order streams within each of Zones 2, 3 and 4. Tables A-10 and A-11 are examples of the calculations all of which were made by individual watersheds, or groups of small watersheds discharging into the Missouri River alluvial plain.

Given the deliveries of sediment by zones it was possible to route the sediment, zone by zone, to the drainage districts; subtracting from the material entering each zone the volume deposited along the main streams therein. By this procedure it was determined:

1 - That approximately 21.52 percent of the sediment deposited in the drainage ditches comes from the major gullies of Division B.

2 - That 43.75 percent of this sediment is the result of sheet erosion and small gullies on the lands of Division A.

3 - That 34.73 percent originates on the lands of Division B.

TABLE A-9. VOLUME OF SEDIMENT DELIVERED TO SECOND ORDER STREAMS IN ACRE-FEET PER SQUARE MILE

Delineation	EROSION				Deposition	Erosion less Deposition
	Sheet	Small Gullies	Trench	Total		
9-B-1	276	2.8		278.8	71.7	207.1
9-B-2	274	3.7		277.7	80.0	197.7
9-C-2 & 3	309	4.8		313.8	138.1	175.7
11-C-2	256	4.7	49.7	300.4	123.5	186.9
11-C-3	251	7.4	40.5	298.9	134.4	164.5
11-D-1	99	1.7	99.4	200.1	40.0	160.1
11-D-2	128	3.5	95.8	227.3	98.1	129.2
11-D-3	250	7.2	192.8	450.0	122.1	317.9
150 - C & D 1 and 2	244	0.6		244.6	140.0	104.6

TABLE A-10. EROSION AND THIRD ORDER SEDIMENT STATUS BY DELINEATIONS AND ZONES FOR DEADMAN AND WHISKEY CREEKS

Zone	Delin-eation	Area in square miles	Erosion Loss Per Square Mile				3rd order sed. per sq. mile	Total Erosion Loss				Total 3rd order sed. vol.
			Gully	Sheet	Total	Trench		Gully	Sheet	Total	Trench	
2	26-A +	2.8	-	-	-	-	-					
	9-B-1	5.3	2.8	276	278.8	-	71.7	15	1465	1480	-	380
	9-B-2	8.5	3.7	274	277.7	-	80.0	31	2330	2361	-	680
	9-C-2&3	2.0	4.8	309	313.8	-	138.1	10	618	628	-	276
	11-C-3	.3	7.4	251	258.4	40.5	134.4	2	75	89	12	40
	Total	18.9						58	4488	4558	12	1376
3	26-A +	1.8	-	-	-	-	-					
	9-B-2	2.5	3.7	274	277.7	-	80.0	9	685	694	-	200
	11-C-2	.6	4.7	256	260.7	49.7	123.5	3	153	186	30	74
	11-C-3	11.0	7.4	251	258.4	40.5	134.4	81.	2760	3286	445	1478
	11-D-3	.4	7.2	250	257.2	192.8	122.1	3	100	180	77	49
	Total	16.3						96	3698	4346	552	1800
4	26-A +	4.7	-	-	-	-	-					
	9-B-2	6.0	3.7	274	277.7	-	80.0	22	1642	1664	-	480
	11-C-2	10.4	4.7	256	260.7	49.7	123.5	49	2660	3225	516	1284
	11-C-3	4.2	7.4	251	258.4	40.5	134.4	31		1292	508	564
	11-D-2	10.0	3.5	128	131.5	95.8	98.1	35		2273	958	981
	11-D-3	14.9	7.2	250	257.2	192.8	122.1	107		6702	2870	1820
	Total	50.2						244	4302	15156	4852	5129

TABLE A-11. NET SEDIMENT CONTRIBUTION (acre-feet) AND PERCENTAGE DISTRIBUTION OF CONTRIBUTION BY DELINEATIONS AND ZONES FOR DEADMAN AND WHISKEY CREEKS

Zone	Delin-eation	Erosion Less 3rd Order Sedimentation			Total net contribu-tion	Percent Contribution			
		Gully	Sheet	Trench		Gully	Sheet	Trench	Total
2	9-B-1	12	1088	-	1100	.4	34.1	-	34.5
	9-B-2	29	1656	-	1685	.9	52.0	-	52.9
	9-C-2 & 3	5	347	-	352	.2	10.9	-	11.1
	11-C-3	1	41	7	49	-	1.3	.2	1.5
	Total	47	3132	7	3186	1.5	98.3	.2	100.0
3	9-B-2	7	487	-	494	.3	19.1	-	19.4
	11-C-2	2	92	18	112	.1	3.6	.7	4.4
	11-C-3	52	1510	244	1806	2.0	59.4	9.6	71.0
	11-D-3	2	73	56	131	.1	2.9	2.2	5.2
	Total	63	2162	318	2543	2.5	85.0	12.5	100.0
4	9-B-2	19	1165	-	1184	.2	11.7	-	11.9
	11-C-2	29	1602	310	1941	.3	15.9	3.1	19.3
	11-C-3	17	594	117	728	.2	5.9	1.2	7.3
	11-D-2	20	728	544	1292	.2	7.3	5.4	12.9
	11-D-3	91	2710	2081	4882	.9	27.0	20.7	48.6
	Total	176	6799	3052	10027	1.8	67.8	30.4	100.0

APPENDIX B

FLOOD AND RELATED DAMAGES

CONTENTS

SECTION I - DAMAGE APPRAISAL

Crop and Pasture Damages on Main Stems

Rural flood damage schedules were taken on farms located in half-mile strips across the valley in each sixth valley mile on the Little Sioux, Maple, West Fork, and Elliott. A completed schedule is shown in Table B-1. Sheet 1 of the schedule was completed for each farm and Sheet 2 was completed for each flood that the owner or operator could recall.

The data on Sheet 2, acres of land flooded and acres destroyed, were tabulated and summarized in the following classification:

1. Stream - Little Sioux, Maple, etc.
2. Time of Occurrence - April 8, 1932, June 13, 1929, etc.
3. Land Use - Corn, small grain, hay, etc.
4. Depth of Inundation - 0 to 1, 1 to 2, 2 to 3, 3 to 4, 4 to 5, and over 5.
5. Duration of Inundation - 0 to 48, 48 to 72, 72 or more hours.

The example used in Table B-2 shows the acres of corn flooded and destroyed by one flood.

Each land use was summarized in this manner for each flood reported.

The different floods as recorded in Table B-2 were summarized by half-month periods in Table B-3. That is, all floods that occurred during any half-month of the growing season, April through September, were grouped regardless of the year of occurrence by the following periods: April 1 to 15, April 15 to 30, May 1 to 15, etc. Thus in the example shown in Table B-2 the totals of all corn acres flooded and destroyed are listed for all floods occurring in the first half of June. The totals of this table therefore show all acres of the crop that were flooded during this part of the season within the memories of the present operators of the sample farms.

The totals of Table B-3 were next summarized for the entire watershed to ascertain what proportion in the flooded area of different crops was destroyed under the various conditions of inundation, during any half-month period. The percentage of corn acreage destroyed from June 1 to June 15 obtained in the above manner is shown in Table B-4. The percentages for the first and last half of each month were then combined to secure a percentage figure for each month in order to have figures on the same basis as hydrologic calculations - Table B-5.

The flooded area of each stream was divided into increments of one foot stages of flooded area. The area inundated to the greatest depth was designated as increment 1. (Table B-1) The area inundated 1 foot less than increment 1 was designated as increment 2, etc. until the entire flooded area was classified as shown on Sheet 2 of the schedules. The acreage of corn, small grain, hay, pasture, and waste in each increment was then summarized from the schedules. These acreages were reduced to a percentage figure as shown in Table B-6.

U.S.D.A.-FLOOD CONTROL SURVEYS - UPPER MISSISSIPPI VALLEY AREA

Stream Little Sioux Reach

Strip No. 21 Photo No. BZK-2-75 Farm No. 3

Inspector Hugo Holm Date of Inspection 9-25 1940

Owner Sorenson Estate Operator Christofferson

Date of Record Flood June 1891

Record Flood: Acreage and land use for season 1940

Land Use	Corn	Sm. Grain Oats - 44 Soy B. - 9	Hay Clover -11 Beans - 10	Pasture	Waste	Other	Total
Flooded	39	53	21	56			169
Not Flooded	17	24		6		4	51
Total	56	77	21	62		4	220

Prospective salvage by reseeding ____ acres to ________ $ ________

Building value $ ________ Damage ________ % $ ________

Loss of Livestock $ ________ Equipment ________ Other ________ $ ________

Debris removal ________ Acres @ ________ silt $ ________ $ ________

Fences, roads, ditches, etc. ________ rds.@ $ ________ $ ________

General Remarks: High water in Little Sioux holds back water in Meadow Creek which then overflows. Drains off when Little Dioux recedes.

(a) Percentage of flood damage chargeable to (1). Main stream water ________ % (2). Main stream deposition ________ %. (3). Side stream and side - hill water ________ %. (4). Side stream and side-hill water deposition ________ %

(b) Approximate number of floods during past 50 years with volumes comparable to those described in detail: (1) ______ (2) ______ (3) ______ (4) ______.

(c) Mention carry over damage if any occurs from water and deposition not covered in current flood damage details.

(d) Give approximate yields in non-flood years: Corn 50 bu. W.Wheat ______ bu. S.Wheat ______ bu. Soybeans 20 bu. Barley 35 bu. Flax 12 bu. Rye ______ bu. Oats 50 Alfalfa hay 2 T. Other hay 1 t. Pasture A.U.M. per 100 acres ______. 1½ per cow

(continued on next page)

TABLE B-1 (continued)

OPERATOR'S NAME Christofferson STRIP NO. ________ PHOTO NO. BZK-2-75

Flood No. ________ Date June 8 1937

Table C

Crop or Land Use Tot. A's Flooded	Estimated percentage of damage and areas inundated at given depths 0'-1' Area	%	1'-2' Area	%	2'-3' Area	%	3'-4' Area	%	4'-5' Area	%	Over 5' Area	%	Hrs. of Duration
Corn													0-48
Corn	14	100	14	100	21	100	14	100					49-72
Sm.Grain													0-48
Sm.Grain	12	100	18	100	15	100	5	100					49-72
Sm.Grain													73 +
Hay													0-48
Hay													49-72
Hay													73 +
Pasture													0-48
Pasture	4	100	11	100	15	100	26	100					49-72
Pasture													73 +
Waste													X
	(4)		(3)		(2)		(1)						

Prospective salvage by reseeding ________ acres to ________ $________
Building value $________ Damage ____ % $________
Loss of Livestock $________ Equip. $________ Other $________ $________
Debris Removal ________ acres @ $________ silt $________ $ 25.00
Fences, roads, ditches, etc. ________ rds. @ $________ $ 40.00

General Remarks: ________

(a) Estimate percentage of flood damage chargeable to (1). Main stream water ____ %
(2). Main stream deposition ____ %. (3). Side stream and side-hill water ____ %
(b) Give approximate number of floods during past 50 years with volumes comparable to those described in detail: (1)____ (2)____ (3)____ (4)____.
(c) Mention carry-over damage if any occurs from water and deposition not covered in current flood damage details.

Hugo Holm
INTERVIEWER

DATE 9-25 19 40

(1) Increment Number

TABLE B-2. TOTAL ACREAGE FLOODED AND CORRESPONDING ACREAGE DESTROYED BY FLOODS ON THE SAMPLE FARMS IN THE FLOOD PLAIN - LITTLE SIOUX RIVER

Land Use	Strip No.	Photo No.	Farm No.	Time of Flood Occurrence	0 to 1 foot depth						1 to 2 feet depth						2 to 3 feet depth					
					0 to 48 hrs.		49 to 72		73 or more		0 to 48 hrs.		49 to 72		73 or more		0 to 48 hrs.		49 to 72		73 or more	
					F 1/	D 2/	F	D	F	D	F	D	F	D	F	D	F	D	F	D	F	D
					acres						acres						acres					
Corn	13	BKK-4-27	2	6-18-37	4	4					3	3										
"	14	BZK-4-48	1	"	6	6					6	6										
"	14	"	2	"	3	3					5	5										
"	15	BZK-1-32	1	"					2	2					4	4					4	4
"	15	"	2	"					4	4					12	12					15	15
"	16	BZK-1-190	1	"					5	5					5	5					10	10
"	16	"	2	"					5	5					10	10					5	5
"	18	BZK-2-109	2	"			10	10														
"	20	BZK-2-75	1	"					16	16					18	18						
"	20	"	2	"					27	27					48	48					25	25
"	20	BZK-2-75	3	"					10	10					25	25					10	10
"	21	BZK-2-45	2	"			30	30					44	44					46	46		
"	21	"	3	"			14	14					14	14					21	21		
				Total	13	13	54	54	69	69	14	14	58	58	122	122	-	-	67	67	69	69

1/ Flooded 2/ Destroyed

(continued on next page)

TABLE B-2. (continued)

Land Use	Strip No.	Photo No.	Farm No.	Time of Flood Occurrence	3 to 4 feet depth						4 to 5 feet depth						Over 5 feet depth					
					0 to 48 hrs.		49 to 72		73 or more		0 to 48 hrs.		49 to 72		73 or more		0 to 48 hrs.		49 to 72		73 or more	
					F 1/	D 2/	F	D	F	D	F	D	F	D	F	D	F	D	F	D	F	D
					acres						acres						acres					
Corn	13	BKK-4-27	2	6-18-37																		
"	14	BZK-4-48	1	"																		
"	14	"	2	"																		
"	15	BZK-1-32	1	"																		
"	15	"	2	"					5	5												
"	16	BZK-1-190	1	"																		
"	16	"	2	"																		
"	18	BZK-2-109	2	"																		
"	20	BZK-2-75	1	"																		
"	20	"	2	"																		
"	20	"	3	"																		
"	21	BZK-2-45	2	"			37	37														
"	21	"	3	"			14	14														
				Total			51	51	5	5												

1/ Flooded   2/ Destroyed

TABLE B-3. TOTAL ACREAGE FLOODED AND CORRESPONDING ACREAGE DESTROYED BY HALF-MONTH PERIODS ON SAMPLE FARMS IN THE FLOOD PLAIN - LITTLE SIOUX RIVER

Land Use	Strip No.	Photo No.	Farm No.	Time of Flood Occurrence	0 to 1 foot depth						1 to 2 feet depth						2 to 3 feet depth					
					0 to 48 hrs.		49 to 72		73 or more		0 to 48 hrs.		49 to 72		73 or more		0 to 48 hrs.		49 to 72		73 or more	
					F 1/	D 2/	F	D	F	D	F	D	F	D	F	D	F	D	F	D	F	D
					acres						acres						acres					
Corn				6-5-02			15	15	35	35			5	5	59	56			5	5	75	75
"				6-10-19	130	20	87	42	168	168	99	14	135	120	367	367			10	10	451	451
"				6-13-29			40	40					142	42					37	37		
"				6-5-31			3	3	50	50			9	9	50	50						
"				6-3-33			14	7					18	10					9	9		
"				6-6-36	10	6	51	50			14	6	85	84			9	1	61	61		
"				6-8-37	13	13	54	54	69	69	14	14	58	58	122	122			67	67	69	69
"				6-3-40	148	61			120	95	6	5	50	25	95	85					25	25
		Total		6-1 to 15	301	100	264	211	442	417	133	39	502	353	693	680	9	1	189	189	620	620

1/ Flooded 2/ Destroyed

(continued on next page)

TABLE B-3. (continued)

Land Use	Strip No.	Photo No.	Farm No.	Time of Flood Occurrence	3 to 4 feet depth						4 to 5 feet depth						Over 5 feet depth					
					0 to 48 hrs.		49 to 72		73 or more		0 to 48 hrs.		49 to 72		73 or more		0 to 48 hrs.		49 to 72		73 or more	
					F 1/	D 2/	F	D	F	D	F	D	F	D	F	D	F	D	F	D	F	D
					acres						acres						acres					
Corn				6-5-02					30	30					5	5						
"				6-10-19					158	158					20	20						
"				6-13-29			20	20														
"				6-5-31																		
"				6-3-33																		
"				6-6-36			36	36														
"				6-8-37			51	51	5	5												
"				6-3-40																		
	Total			6-1 to 15			107	107	193	193					25	25						

1/ Flooded 2/ Destroyed

TABLE B-4. PERCENT OF FLOODED CROP AREA DESTROYED BY HALF-MONTH PERIODS BY VARIOUS DEPTHS AND DURATIONS OF INUNDATION

Depth and Duration	Date	Land Use	Percent of Flooded Crops Destroyed
0 - 1'			
0-48 hours	6-1 to 6-15	Corn	29
49-72 hours	"	"	86
73 + hours	"	"	96
1 - 2'			
0-48 hours	"	"	32
49-72 hours	"	"	92
73 + hours	"	"	99
2 - 3'			
0-48 hours	"	"	36
49-72 hours	"	"	99
73 + hours	"	"	100
3 - 4'			
0-48 hours	"	"	40 1/
49-72	"	"	100
73 - hours	"	"	100
4 - 5'			
0-48 hours	"	"	50
49-72 hours	"	"	100
73 + hours	"	"	100
Over 5'			
0-48 hours	"	"	60
49-72 hours	"	"	100
73 + hours	"	"	100

1/ Figures underlined are interpolated.

TABLE B-5. PERCENT OF FLOODED CROP AREA DESTROYED BY MONTHS BY VARIOUS DEPTHS AND DURATIONS OF INUNDATION

Depth and Duration	Date	Land Use	Percent of Flooded Area Destroyed
0 - 1'			
0-48 hours	6-1 to 6-15	Corn	50
49-72 hours	"	"	82
73 + hours	"	"	95
1 - 2'			
0-48 hours	"	"	52
49-72 hours	"	"	87
73 + hours	"	"	100
2 - 3'			
0-48 hours	"	"	68
49-72 hours	"	"	100
73 + hours	"	"	100
3 - 4'			
0-48 hours	"	"	70
49-72 hours	"	"	100
73 + hours	"	"	100
4 - 5'			
0-48 hours	"	"	75
49-72 hours	"	"	100
73 + hours	"	"	100
Over 5'			
0-48 hours	"	"	80
49-72 hours	"	"	100
73 + hours	"	"	100

Miscellaneous flood damage consisting of debris removal, damage to fences, etc., as listed on Sheet 2 of the schedules, was summarized. This total damage was divided by the total acres flooded to determine the damage per acre of the area flooded of each stream - Table B-7.

The total acres destroyed as given on Sheet 2 of the schedule were summarized by crops into four classifications; damage done by (1) main stream water, (2) main stream deposition, (3) side stream and side hill water, (4) side stream and side hill deposition.

Average yields per acre of all crops in the flood plain were summarized from Sheet 1 of the schedule. These represent average yields in the flood plain for non-flood years.

The 1940 land use on the area flooded in 1891 as shown on Sheet 1 of the schedule was summarized to obtain the total acres of each crop produced. These acreages were converted to a percentage figure for the broad classifications of corn, small grain, hay, pasture, waste and other. The acreages of small grain and hay were further broken down to a percentage in the flood plain.

The average farm prices of agricultural commodities based on 1930 to 1939 farm prices in Northwest Iowa were used - Table B-8. These prices combined with the average yields of non-flood years were used in computing the value per acre of all crops in the flood plain. A composite value per acre of all small grain and hay crops was computed on the percentage of the total acreage each represents - Table B-9 and Table B-10.

In order to determine flood damage to any crop during the growing season, the following basic data and assumptions were used:

The percentage of farm work done by tractors in Iowa 1/ is as follows: Plowing 82 percent, corn cultivating 58 percent, corn planting 10 percent, disking 75 percent, harrowing 64 percent.

Labor power and machinery charges were assumed as follows:

Man labor	$ .20 per hour	2/
Horse power	.09 per hour	2/
Tractor (2 plow)	.55 per hour	2/
Machinery cost per acres of corn (husked)	1.24	3/
Machinery cost per acres of small grain	.90	3/
Machinery cost per acres of hay	.40	3/

Cash tractor costs (including fuel and oil and miscellaneous costs) 4/ are estimated at approximately 60 percent of the total tractor costs. Costs of horse power are assumed to be non-cash-items.

Footnotes 1, 2, and 3 are listed at the bottom of page B-3.

TABLE B-6. LAND USE PERCENTAGES BY INCREMENTS

Land Use	Increment Number					
	1	2	3	4	5	6
	%	%	%	%	%	%
Corn	21.1	33.5	35.1	41.3	41.8	52.1
Small Grain	14.7	18.8	19.4	21.8	17.4	13.7
Hay	1.4	1.6	1.8	2.8	11.7	6.8
Pasture	51.6	44.9	42.5	33.3	29.1	27.4
Waste	11.2	1.2	1.2	.8	.0	.0

TABLE B-7. MISCELLANEOUS AGRICULTURAL FLOOD DAMAGE PER ACRE FLOODED 1/

Stream	Average Damage Per Acre
Little Sioux	$ 0.13
Maple	.08
West Fork	.48
Elliott	.43

1/ Fence damage, debris removal, etc.

TABLE B-8. AVERAGE FARM PRICES IN THE LITTLE SIOUX RIVER WATERSHED 1/

Commodity	Farm Price
Grains per bushel	
Corn	$ 0.53
Wheat	.74
Oats	.28
Barley	.47
Soybeans	.97
Shelling charge	.01
Roughage per ton	
Alfalfa hay	10.00
Mixed hay	7.50
Soybean hay	8.75
Wild hay	6.00
Oats hay	6.50
Sudan hay	7.00
Straw	1.25
Seed per bushel	
Corn	5.00
Alfalfa	13.00
Red clover	12.00
Sweet clover	4.00

1/ Division of crops and livestock estimates of Iowa districts 1 and 4.

TABLE B-9. COMPOSITE VALUE PER ACRE OF SMALL GRAIN

Crop	Yield per acre (bu.)	Price per bushel $	Value per acre $	Percentage of total acreage %	Composite value per acre $
Oats	40	0.28	11.20	36	4.03
Barley	32	.47	15.04	22	3.31
Wheat	25	.74	18.50	34	6.29
Soybeans	23	.97	22.31	8	1.78
TOTAL					15.41

TABLE B-10. COMPOSITE VALUE PER ACRE OF HAY

Crop	Yield per acre (tons)	Price per ton $	Value per acre $	Percentage of total acreage %	Composite value per acre $
Oats	1	6.50	6.50	9	.59
Soybeans	2	8.75	17.50	35	6.13
Clover	1.9	8.00	15.20	26	3.95
Alfalfa	2.2	10.00	22.00	23	5.06
Mixed	1.1	6.50	7.15	7	.50
TOTAL					16.23

Cash Machinery Costs per Operation: Cash machinery costs are assumed to be distributed to various operations as follows:

	Estimated Cost per Acre
Corn	
Plowing	$ 0.30
Disking	.10
Harrowing	.05
Planting	.15
Harrowing	.05
Cultivating (3 at 10¢ each)	.30
Husking (50 percent done by machine (60¢ ÷ 2))	.30
	$ 1.25
Small Grain	
Plowing	.30
Disking	.10
Seeding	.15
Harrowing	.05
Cutting	.30
	$ 0.90
Hay	
Cutting	.20
Raking	.05
Putting in barn	.15
	$ 0.40

1/ U.S.D.A. Press release, Des Moines Register, November 24, 1940.

2/ Minn. Agri. Exp. Sta. Mimeograph Report No. 106.

3/ Second Annual Report-Northwest Iowa Farm Business Association 1939. Average crop machinery inventory was $847. Average cash expense for equipment $104,00 per farm. Assuming 10 percent crop machinery depreciation per year, depreciation and cash equipment expense equal approximately $1.00 per crop acre. Crop production cost in Winona County, Minn. 2/ indicates that relative machinery cost per acre of corn, small grain, and hay are approximately in the ratio of 3, 2, and 1 respectively. These ratios were used as weights and multiplied by land use percentages (50 percent of cropland in corn, 35 percent small grain and 15 percent hay) to secure estimated machinery cost per acre of corn, small grain and hay.

4/ Minnesota Agricultural Experiment Station Mimeograph Report No. 107.

Selected costs per acre of various farming operations:

		Total costs selected items		Cash costs for use in estimating flood losses
Corn				
Plowing				
Man labor	1.6 hours	$ .32	(About 50% assumed hired)	.17
Tractor	1.6 hours	.88		.53
Machinery		.30		.30
		$ 1.50		$ 1.00
Replanting (2-Disking, 2-Harrowing and Planting)				
Seed		.61		.61
Man labor	1.8 hours 5/	.36		
Horse power	6.0 hours 5/	.54		
Machinery		.45		.45
		$ 1.96		$ 1.06
Cultivating				
Man labor	.8 hours 5/	.16	50%	.08
Horse power	5/1.6 hrs.50%	.14		
Tractor	5/ .24 hrs50%	.13	60%	.08
Machinery		.10		.10
		$ 0.53		$ 0.26
Husking				
By hand				
Man labor	6 hours 5/	1.20	50%	.60
Horse power	11.1 hrs5/	1.00		
		$ 2.20		
By machine				
Man labor		.30		.15
Fuel		.18		.18
Oil and grease		.05		.05
Tractor use		.25		.25
Repair on picker		.06		.06
Depreciation		.41		.41
Interest on investment		.10		.10
Shelter Cost		.02		.02
Fire Insurance		.04		.04
Taxes		.01		-
		$ 1.42		$ 1.26
Total cost per acre 6/				
Man labor (hauling and storing)		.60		,30
Horse power		.54		-
		$ 2.56		$ 1.56

5/ Minn. Agri. Exp. Sta. Tech. Bul. 138. "Farm Organization for Beef Cattle Production in Southwestern Minnesota"

6/ Dept. of Agri. Economics, U of Illinois, "The Cost of Harvesting Corn with Two-Row Mechanical Corn Picker East Central Illinois". Sept.1938.

The following per acre flood losses are based on 100 percent destruction of the crop and are computed for half-month periods.

Flood Damage to Corn:

April 1 - 15		
Corn not planted — replowing the only loss		
Cash cost of replowing		$ 1.00
FLOOD LOSS		1.00
April 16 - 30		
Cash cost of replowing		1.00
FLOOD LOSS		1.00
May 1 - 15		
Corn replanted to corn with no reduction in yield		
Replanting cost the only loss		
Cash cost of replanting		1.06
FLOOD LOSS		1.06
May 16 - 31		
Corn replanted to corn yield reduced to 30 bu. per acre		
Value of original crop 51 bu. @ $0.53		27.03 per acre
Cash cost of shelling deducted	.51	
Cash cost of husking deducted	1.08	
Cash cost of 3 cultivations deducted	.78	
Total cash costs deducted	$2.37	24.66 per acre
Cash cost of replanting added	1.06	25.72 per acre
Cash cost of producing substitute crop added	1.86	27.58 per acre
Value of replanted crop (30 bu. @	$0.53	15.90 per acre
Cash cost of shelling deducted	.30	15.60 per acre
FLOOD LOSS $27.58 minus $15.60		11.98 per acre
June 1 - 15		
Corn replanted to soybeans for hay		
Values of original crop		27.03 per acre
Cash cost of shelling deducted	.51	
Cash cost of husking deducted	1.08	
Cash cost of 2 cultivations ded.	.52	
Total cash costs deducted	2.11	24.92 per acre
Cash cost of replanting added	1.60	26.52 per acre
Cash cost of harvesting replant crop added	.76	27.28 per acre
Value of replant crop 3/4 ton @ $8.75		6.56
FLOOD LOSS $27.28 minus $6.56		20.72
June 16 - 30		
Too late to replant any crop		
Value of original crop		27.03 per acre
Cash cost of shelling deducted	.51	
Cash cost of husking deducted	1.08	
Cash cost of 1 cultivation ded.	.26	
Total cash costs deducted	1.85	25.18 per acre
FLOOD LOSS		25.18 per acre

July 1 to harvesting time		
Value of original crop		27.03 per acre
Cash cost of shelling deducted	.51	
Cash cost of husking deducted	1.08	
Total cash costs deducted	1.59	25.44 per acre
FLOOD LOSS		25.44 per acre

Flood Damage to Small Grain (Wheat, Oats, Barley and Soybeans):

April 1 - 15		
Composite value of original small grain crop weighted by percentage of each crop in flood plain, Wheat 34%, Oats 36%, Barley 22%, Soybeans 8%.		15.41 per acre
Cash cost of threshing deducted (W.,O.,B.)	1.07	
Cash cost of harvesting deducted(W.,O.,B.)	.63	
Total cash costs deducted	1.70	13.71 per acre
Cash cost replowing soybeans added	.08	13.79 per acre
Reseeded to oats or barley (weighted — Oats 62%, Barley 38%)		
Cash cost of replanting added	1.47	15.26 per acre
Cash cost of harvesting and threshing replant crop added $1.11 and $0.69 or $1.80		17.06 per acre
Value of replant crop (weighted)		12.65 per acre
FLOOD LOSS $17.06 minus $12.65		4.41 per acre
April 16 - 30		
Value of original crop		15.41 per acre
Unexpended cash costs deducted	1.07	13.71 per acre
Cash costs replowing added	.08	13.79 per acre
Cash cost of reseeding added	1.47	15.26 per acre
Cash cost of harvesting replant crop added	.76	16.02 per acre
Reseeded to Oats and Soybean hay -- 50% each. Yield--Oats 1 ton, beans 2 tons. Composite value of replant crop - Oats $6.50, beans $17.50		12.00 per acre
FLOOD LOSS $16.02 minus $12.00		4.02 per acre
May 1 - 15		
Value of original crop		15.41 per acre
Total unexpended cash costs deducted		
Cultivation	0.06	
Threshing	1.20	
Harvesting	.69	
Total-	1.95	13.46 per acre
Reseeded to soybeans for hay (yield 1-1/2 tons)		
Cash cost of reseeding added	1.60	15.06
Cash cost of harvesting replant crop added	.76	15.82
Value of replant crop (1-1/2T @ $8.75)		13.12 per acre
FLOOD LOSS $15.82 minus $13.12		2.70 per acre

May 16 – 31		
Value of original crop		15.41 per acre
Unexpended cash costs deducted	1.89	13.52 per acre
Cash cost of 3 cultivations (S.B.) deducted	.06	13.46 per acre
Reseeded to soybean hay (yield 1 ton)		
Cash cost of reseeding added	1.60	15.06 per acre
Cash cost of harvesting replant crop added	.76	15.82 per acre
Value of replanted crop (1 T. @ $8.75)		8.75 per acre
FLOOD LOSS $15.82 minus $8.75		7.07 per acre
June 1 – 15		
Value of original crop		15.41 per acre
Unexpended cash costs deducted	1.89	13.52 per acre
Cash cost of 1 cultivation ded S.B.	.02	13.50 per acre
Reseeded to soybean hay (yield 3/4 ton)		
Cash cost of reseeding added	1.60	15.10 per acre
Cash cost of harvesting replant crop added	.76	15.86 per acre
Value of replant crop (3/4 T @ $8.75)		6.56 per acre
FLOOD LOSS $15.86 minus $6.56		9.30 per acre
June 16 – 30		
Too late to replant any crop		
Value of original crop		15.41 per acre
Total unexpended cash costs deducted	1.89	13.52 per acre
FLOOD LOSS		13.52 per acre
July 1 – 15		
Value of original crop		15.41 per acre
Total unexpended cash costs deducted	1.89	13.52 per acre
FLOOD LOSS		13.52 per acre
July 16 – August 15		
Soybeans not cut		
Value of original crop		15.41 per acre
Cash cost of threshing deducted	1.20	14.21 per acre
Cash cost of harvesting soybeans ded.	.06	14.15 per acre
FLOOD LOSS		14.15 per acre
August 16 – October 15		
Soybeans not harvested		
Value of original crop		15.41 per acre
Less oats, barley, wheat (weighted)	13.63	1.78 per acre
Less cash costs of harvesting and threshing soybeans	.19	1.59 per acre
Cash cost of replowing small grain land added	.92	2.51 per acre
FLOOD LOSS		2.51 per acre
October 16 – March 31		
Cash cost of replowing		1.00 per acre

Flood Damage to Hay (Oats, Soybeans, Alfalfa, Clover, and Mixed): The composite percentage of each in the flood plain. Oats 9%, Alfalfa 26%, Clover 23%, Mixed 7%.

			Weighted Damage
April 1 - 15			
Oats reseeded to oats, no reduction in yield			
Cash cost of reseeding $1.24 x 9%		+	$ 0.11
Soybean replowing $1.00 x 35%		+	.35
Alfalfa reseeded to soybeans			
Alfalfa (Value of crop 2.2T @ $10)	$22.00		
Unexpended cash cost deducted (3 cuttings $2.28)	19.72		
Cash cost of plowing added $1.00	20.72		
Cash cost of reseeding added $1.60	22.32		
Cash cost of harvesting replant crop added $0.76	23.08		
Value of soybean crop (2T @ $8.75)	17.50		
FLOOD LOSS $23.08 minus $17.50 - 5.58 x 26%			1.45
Clover reseeded to soybeans			
Value of clover crop (1.9 T. @ $8.00)	15.20		
Unexpended cash costs deducted (2 cuttings) 1.52	13.68		
Cash cost of plowing added 1.00	14.68		
Cash cost of reseeding added 1.60	16.28		
Cash cost of harvesting replant crop added 0.76	17.04		
Value of soybean crop (2T. @ $8.75)	17.50		
FLOOD LOSS $9.75 minus $17.50 minus $7.75 x 7% minus FLOOD LOSS			.11
Mixed hay reseeded to soybeans			
Value of mixed hay (1.1 T. @ $6.50	7.15		
Unexpended cash cost deducted .76	6.39		
Cash cost of plowing added 1.00	7.39		
Cash cost of reseeding added 1.60	8.99		
Cash cost of harvesting replant crop added .76	9.75		
Value of soybean crop (2T. @ $8.75)	17.50		
FLOOD LOSS $9.75 minus $17.50 minus $7.75 x 7% minus			.54
FLOOD LOSS			1.26 per acre
April 16 - 30 - same as April 1 - 15			
FLOOD LOSS			1.26 per acre
May 1 - 15			
Oats reseeded to soybeans			
Value of oats crop (1T. @ $6.50)	6.50		
Unexpended cash cost ded. .76	5.74		
Cash cost of plowing and reseeding added 2.60	8.34		
Cash cost of harvesting replant crop added .76	9.10		
Value of soybeans (1-1/2T. @ $8.75)	13.12		
FLOOD LOSS $9.10 minus $13.12 minus $4.02 x 9%			.36

May 1 - 15 (continued) | Weighted Damage

Soybeans reseeded to soybeans

Value of original crop (2T. @ $8.75)		17.50	
Unexpended cash costs deducted	.76	16.74	
Cash cost of reseeding added	1.60	18.34	
Cash cost of harvesting replant crop added	.76	19.10	
Value of replant crop(1-1/2T.@ $8.75)		13.12	
FLOOD LOSS $19.12 minus $13.12 - 5.98 x 35% plus			2.09

Alfalfa reseeded to soybeans

Value of original crop		22.00	
Unexpended cash costs ded.	2.28	19.72	
Cash cost of plowing and reseeding added	2.60	22.32	
Cash cost of harvesting replant crop added	.76	23.08	
Value of replant crop(1-1/2T.@$8.75)		13.12	
FLOOD LOSS $23.08 minus $13.12 - $9.96 x 26% plus			2.59

Clover reseeded to soybeans

Value of original crop		15.20	
Unexpended cash costs ded.	1.52	13.68	
Cash costs of plowing and reseeding added	2.60	16.28	
Cash costs of harvesting replant crop added	.76	17.04	
Value of replant crop		13.12	
FLOOD LOSS $17.04 - $13.12 - $3.92 x 23% plus			0.90

Mixed reseeded to soybeans

Value of original less unexpended cash costs		6.39	
Cash cost of plowing and reseeding added	2.60	8.99	
Cash cost of harvesting replant crop	.76	9.75	
Value of replant crop		13.12	
FLOOD LOSS $9.75 minus $13.12 minus $3.37 x 7% minus			0.24
FLOOD LOSS			4.98 per acre

May 16 - 31

Oats reseeded to soybeans

Value of original crop (plus additions and less reductions)		8.34	
Cash cost of harvesting replant crop added	0.76	9.10	
Value of replant crop (1T. @ $8.75)		8.75	
FLOOD LOSS $9.10 minus $8.75 - $0.35 x 9%			0.03

Soybeans reseeded to soybeans

Value of original crop (plus additions and less reductions)		18.34	
Cash cost of harvesting replant crop added	0.76	19.10	
Value of replant crop (1 T.@ $8.75)		8.75	
FLOOD LOSS $19.10 minus $8.75 - $10.35 x 35%			3.62

May 16 - 31 (continued)			Weighted Damage
Alfalfa reseeded to soybeans			
Value of original crop (plus additions and less reductions)		22.32	
Cash cost of harvesting replant crop added	0.76	23.08	
Value of replant crop		8.75	
FLOOD LOSS $23.08 minus $8.75 - $14.33 x 26%			3.73
Clover reseeded to soybeans			
Value of original crop (plus additions and less deductions)		16.28	
Cash cost of harvesting replant crop added	0.76	17.04	
Value of replant crop		8.75	
FLOOD LOSS $17.04 minus $8.75 - $8.29 x 23%			1.91
Mixed reseeded to soybeans			
Value of original crop (plus additions and less deductions)		8.99	
Cash cost of harvesting replant crop added	0.76	9.75	
Value of replant crop		8.75	
FLOOD LOSS $9.75 minus $8.75 - 1.00 x 7%			.07
FLOOD LOSS			9.36 per acr
June 1 - 15			
Oats reseeded to soybeans			
Value of original crop (pluss additions and less deductions)		8.34	
Cash cost of harvesting replant crop added	0.76	9.10	
Value of replant crop(3/4T.@ $8.75)		6.56	
FLOOD LOSS $9.10 minus $6.56 -- $2.54 x 9%			0.23
Soybeans reseeded to soybeans			
Value of original crop (plus additions and less deductions)		18.34	
Cash cost of harvesting replant crop added	0.76	19.10	
Value of replant crop		6.56	
FLOOD LOSS $19.10 minus $6.56 — $12.54 x 35%			4.39
Alfalfa to Soybeans			
Value of original crop (less 1 cutting $7.33)		14.67	
Unexpended cash cost ded.	1.52	13.15	
Cash cost of plowing and reseeding added	2.60	15.75	
Cash cost of harvesting replant crop added	0.76	16.51	
Value of replant crop		6.56	
FLOOD LOSS $16.51 - $6.56 — $9.95 x 26%			2.59 per acr

			Weighted Damage
June 1 - 15 (continued)			
Clover to soybeans			
Value of clover (plus additions and less deductions)		16.28	
Cash cost of harvesting replant crop added	0.76	17.04	
Value of replant crop		6.56	
FLOOD LOSS $17.04 - $6.56 — $10.48 x 23%			2.41
Mixed to soybeans			
Value of mixed crop (plus additions and less deductions)		8.99	
Cash cost of harvesting replant crop added	0.76	9.75	
Value of replant crop		6.56	
FLOOD LOSS $9.75 - $6.56 — $3.19 x 7%			0.22
FLOOD LOSS			9.84 per acre
June 16 - 30 (Too late to reseed any crop)			
Value of oats hay		6.50	
Less unexpended cash costs	0.76	5.74	
FLOOD LOSS $5.74 x 9%			0.52
Value of soybeans		17.50	
Less unexpended cash costs	0.76	16.74	
FLOOD LOSS $16.74 x 35%			5.86
Value of alfalfa (less 1 cutting)		14.67	
Less unexpended cash costs	1.52	13.15	
FLOOD LOSS $13.15 x 26%			3.42
Value of clover		7.60	
Less unexpended cash costs	0.76	6.84	
FLOOD LOSS $6.84 x 23%			1.57
Value of mixed hay		7.15	
Less unexpended cash costs	0.76	6.39	
FLOOD LOSS $6.39 x 7%			0.45
FLOOD LOSS			11.82 per acre
July 1 - 15			
Oats harvested		17.50	
Value of soybeans	0.76	16.74	
Flood loss $16.74 x 35%			5.86
Alfalfa flood loss			3.42
Clover flood loss			1.57
Mixed hay flood loss			0.45
FLOOD LOSS			11.30 per acre
July 16 - August 31			
Oats harvested			
Soybean flood loss			5.86
Value of alfalfa		7.33	
Less unexpended cash costs	0.76	6.57	
Flood loss $6.57 x 26%			1.71
Clover flood loss			1.57
Mixed hay flood loss			.45
FLOOD LOSS			9.59

September 1 - 15	
Soybean - flood loss	5.86
Mixed hay - flood loss	.45
FLOOD LOSS	6.31
September 16 - March 31	
All hay crops harvested	
No loss	

In computing flood damage per acre to pasture by half-month periods, it was assumed that pasture damaged by any flood was lost for the remainder of the year only, and that it comes back to full production the following year. The loss was assumed to be the unused portion, prorated by half-month periods. The grazing period covers the six months, May to October, inclusive. The average rent paid is $3.00 per acre. Carrying capacity is two acres per animal unit for the six month period.

	Damage per acre
April 1 to 15	
Flood loss	$3.00
April 16 to 30	
Flood loss	3.00
May 1 to 15	
Flood loss	2.87
May 15 to 31	
Flood loss	2.62
June 1 to 15	
Flood loss	2.37
June 16 to 30	
Flood loss	2.12
July 1 to 15	
Flood loss	1.87
July 16 to 31	
Flood loss	1.62
August 1 to 15	
Flood loss	1.37
August 16 to 31	
Flood loss	1.12
September 1 to 15	
Flood loss	.87
September 16 to 30	
Flood loss	.62
October 1 to 15	
Flood loss	.37
October 16 to 31	
Flood loss	.12

The following per acre flood losses are based on 100% destruction of this crop and are computed for each month of the growing season. Each monthly figure is an average of the first and second half of the month.

Flood Damage to Corn:

April	1.00 per acre
May	6.52
June	22.95

TABLE B-11. FLOOD DAMAGE PER ACRE OF CORN FLOODED BY DEPTH AND DURATION OF INUNDATION FOR EACH MONTH OF THE GROWING SEASON

Depth and Duration of Inundation	April	May	June	July	August	September
0-1 foot						
0-48 hours	.30	1.65	11.50	5.10	1.25	1.00
49-72 hours	.30	4.25	18.80	5.35	2.55	1.00
73 + hours	.30	4.25	21.80	11.95	6.35	1.00
1-2 feet						
0-48 hours	.30	1.95	11.95	5.85	1.25	1.00
49-72 hours	.30	4.45	19.95	14.25	5.35	1.00
73 + hours	.30	4.45	22.95	18.55	12.20	1.00
2-3 feet						
0-48 hours	.30	2.30	15.60	14.75	2.55	1.50
49-72 hours	.30	4.45	22.95	19.35	8.40	1.50
73 + hours	.30	4.45	22.95	25.45	17.80	1.50
3-4 feet						
0-48 hours	.30	2.30	16.05	16.55	6.10	4.55
49-72 hours	.30	4.45	22.95	21.10	11.45	4.55
73 + hours	.30	4.45	22.95	25.45	19.10	4.55
4-5 feet						
0-48 hours	.30	2.30	17.20	18.55	9.65	8.15
49-72 hours	.30	4.45	22.95	22.90	15.25	8.15
73 + hours	.30	4.45	22.95	25.45	21.60	8.15
Over 5 feet						
0-48 hours	.30	2.30	18.35	20.35	12.20	11.95
49-72 hours	.30	4.45	22.95	24.15	17.80	11.95
73 + hours	.30	4.45	22.95	25.45	22.90	11.95

Damage schedules were also taken on minor tributaries. An estimate of average annual damage per mile of stream was made directly from these schedules. The total annual damage on minor tributaries was then determined by multiplying the per mile damage rate by the miles of tributary affected.

July	25.44 per acre
August	25.44
September	25.44

Flood Damage to Small Grain:

April	4.22 per acre
May	4.89
June	11.41
July	13.84
August	8.18
September	2.51

Flood Damage to Hay:

April	1.26 per acre
May	7.17
June	10.83
July	10.45
August	9.59
September	3.15

Flood Damage to Pasture:

April	3.00 per acre
May	2.75
June	2.25
July	1.75
August	1.25
September	.75

The flood damage per acre to each crop was computed for each depth and duration class for each month of the growing season. The damage to corn is shown in Table B-11. These flood damage figures were obtained by multiplying the crop damage in each month, as shown above, by the percentage destruction for each crop. A sample of the percentage destruction of corn is shown in Table B-5.

Crop and Pasture Damages on Tributaries

Flood damages on tributary streams were obtained by taking field schedules at half mile intervals along all streams sufficiently large to have been given a name. The length of tributary streams on which damages are experienced was determined by speedometer readings and map measurements and the average width of flooding estimated from information supplied by residents.

Fence, Highway and Railroad Damages

Flood damages to fences, highways and railroads were determined by field appraisal.

Damages on Missouri River Alluvial Plain

Damages to crops and pastures on the Missouri river - alluvial plain were determined by the U. S. Engineer Department in the course of an uncompleted flood control survey of the Little Sioux Basin.

The filling of drainage ditches in this area with sediment derived from the uplands of the watershed was determined by a study of the cost of dredging ditches.

SECTION II - DISCHARGE-DAMAGE RELATIONSHIPS

The flood damage to crops was determined by field appraisal based on the depth of water and the time of inundation as discussed in Section I. In order to apply the damage factors in this form it was necessary to determine the depth and time of inundation for any flooded area. To do this stream flow records were used to determine the average shape of the hydrograph of the streams. Hydrographs were then set up for several cross-sections for concordant flows. Figure B-1 was prepared showing the time of inundation for any flow at the cross-sections for which hydrographs were prepared. By interpolating between the lines shown, the time of inundation can be determined for any flow at every cross-section. Knowing the damage done to crops for various depths and times of inundation and knowing the land use on the area flooded, the damage for any flood was computed. Floods of different magnitudes were selected to cover the range and the damage computed for the months of April through September, [redacted]. The damage per acre for other flooded was determined as shown in Table B-13. Damage per acre for other floods was determined by interpolation and the total damage computed by multiplying by the acres flooded. The values were plotted in constructing the discharge damage curves for each stream and are shown in Figures B-2, B-3, B-4, B-5, B-6, B-7, B-8, and B-9.

WEST FORK
TIME OF INUNDATION

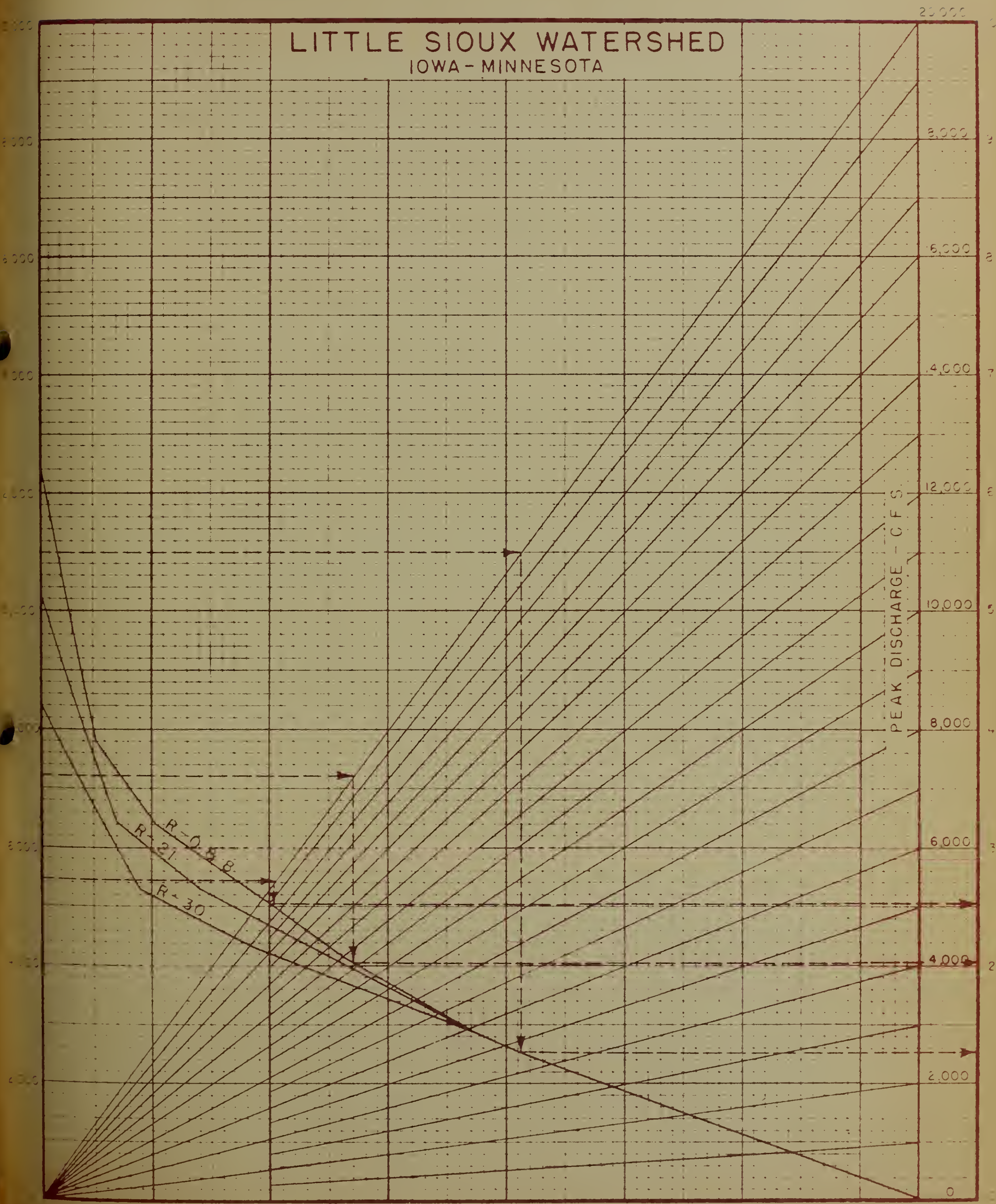


Fig. No. B-1

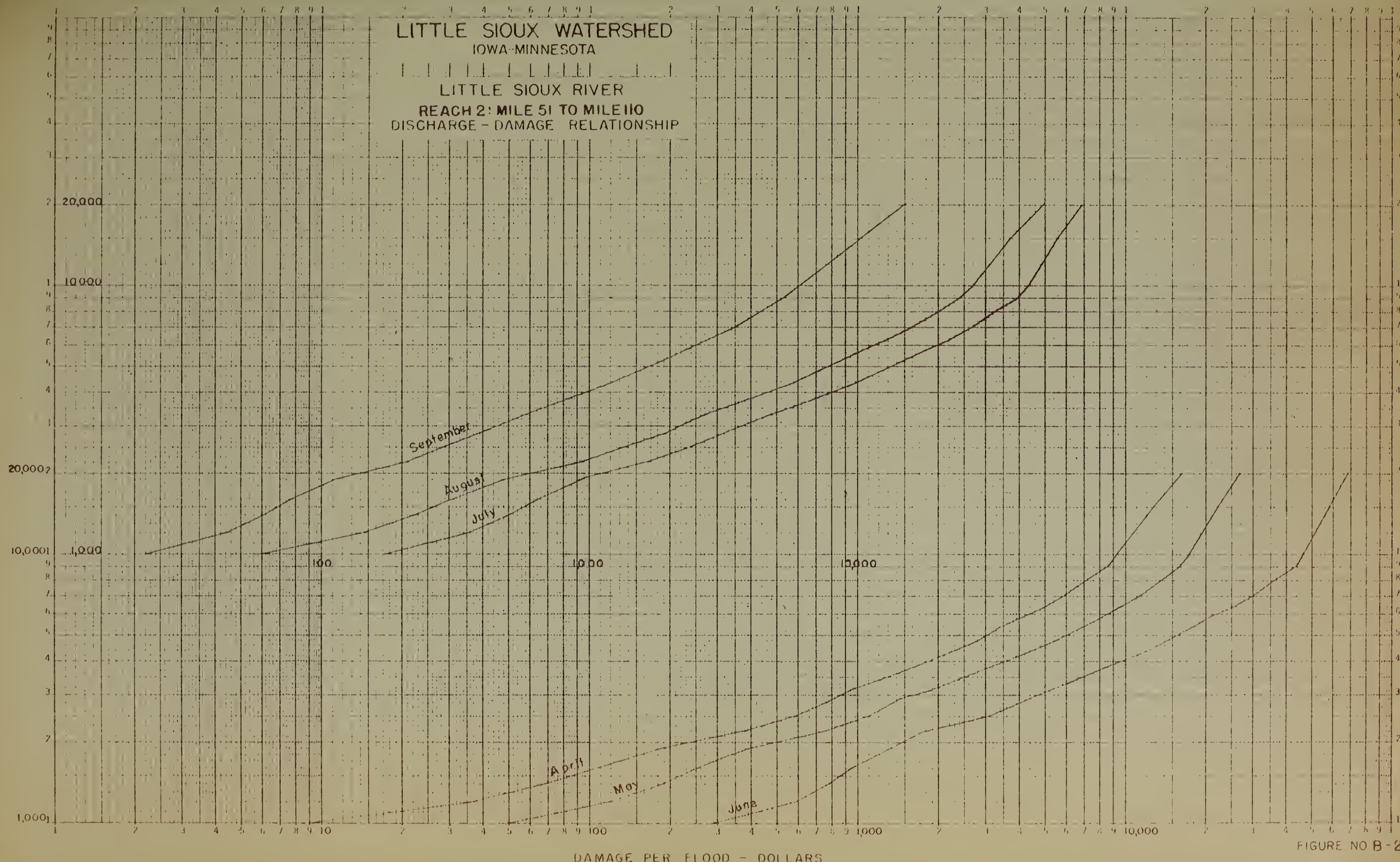


FIGURE NO B-2

CROP AND PASTURE

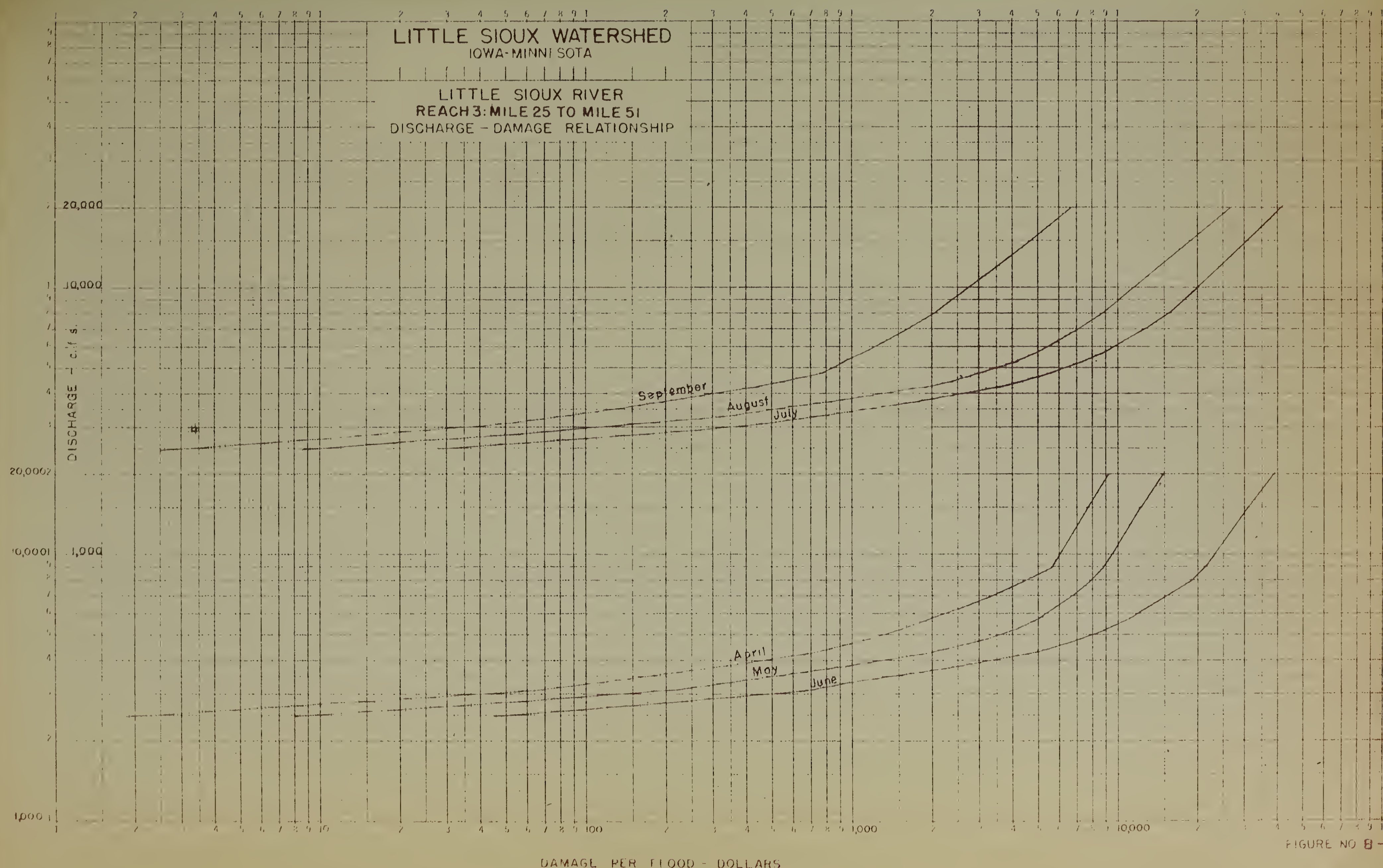


FIGURE NO B-3

CROP AND PASTURE

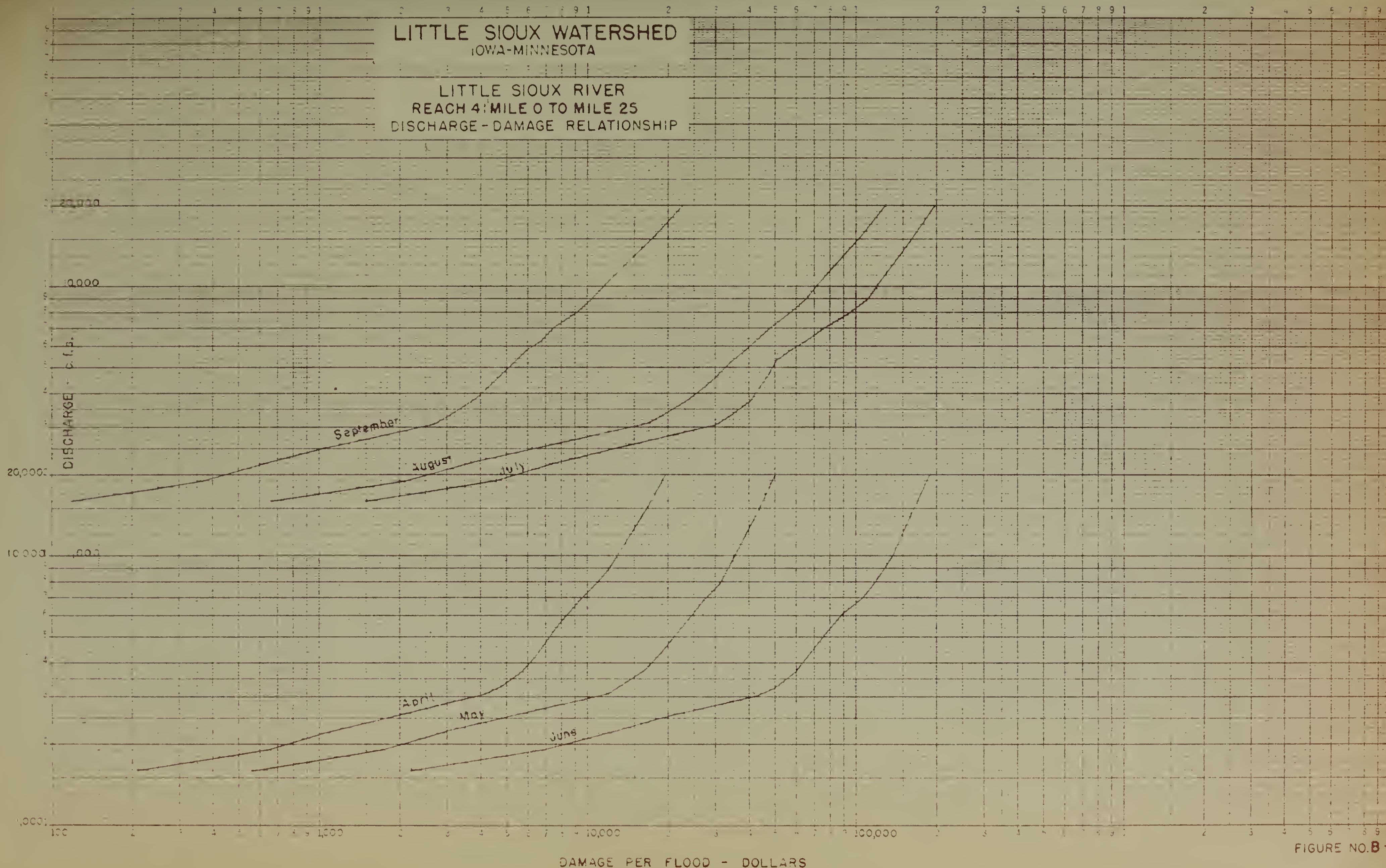


FIGURE NO. B-

CROP AND PASTURE.

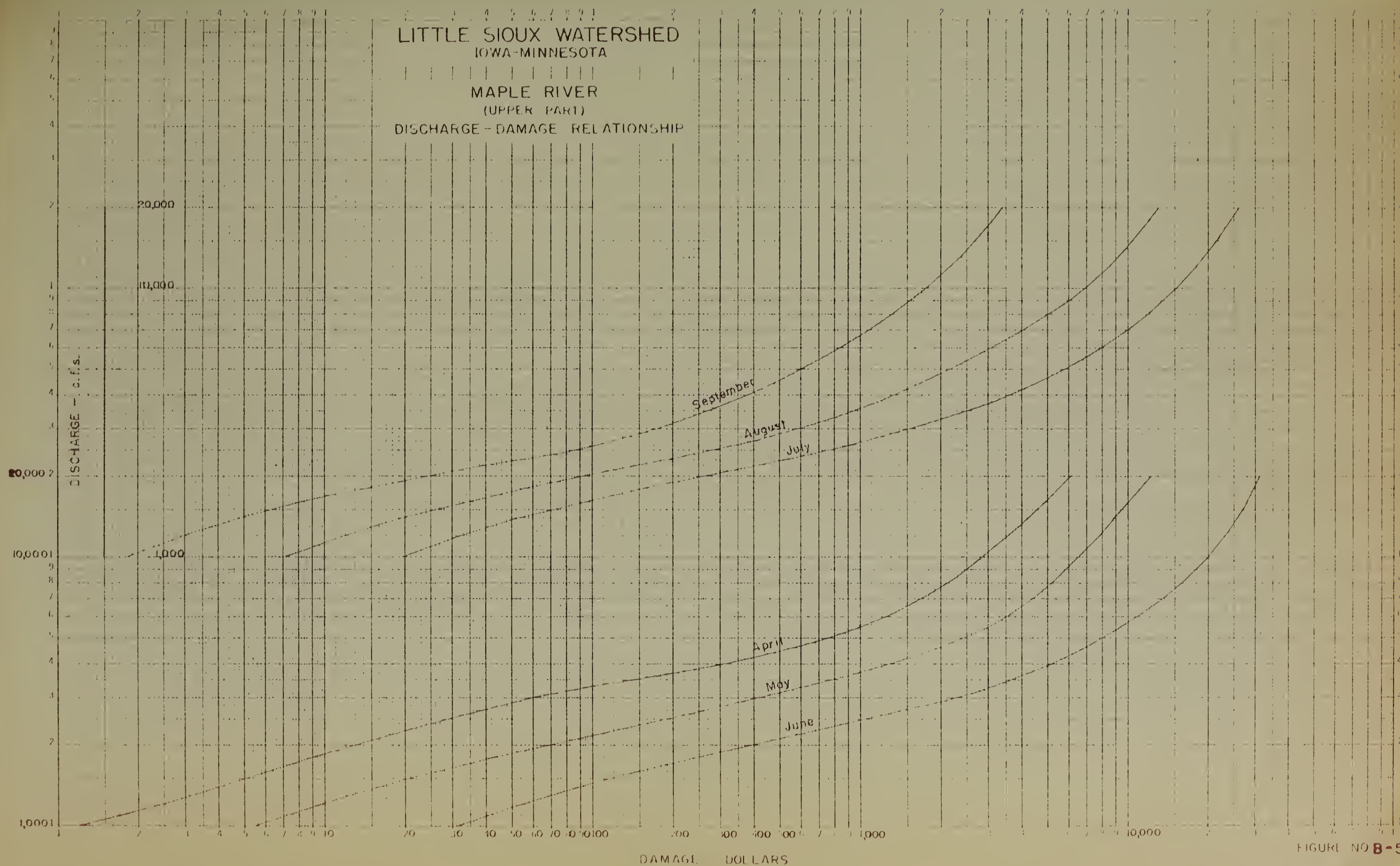


FIGURE NO B-5

CROP AND PASTURE

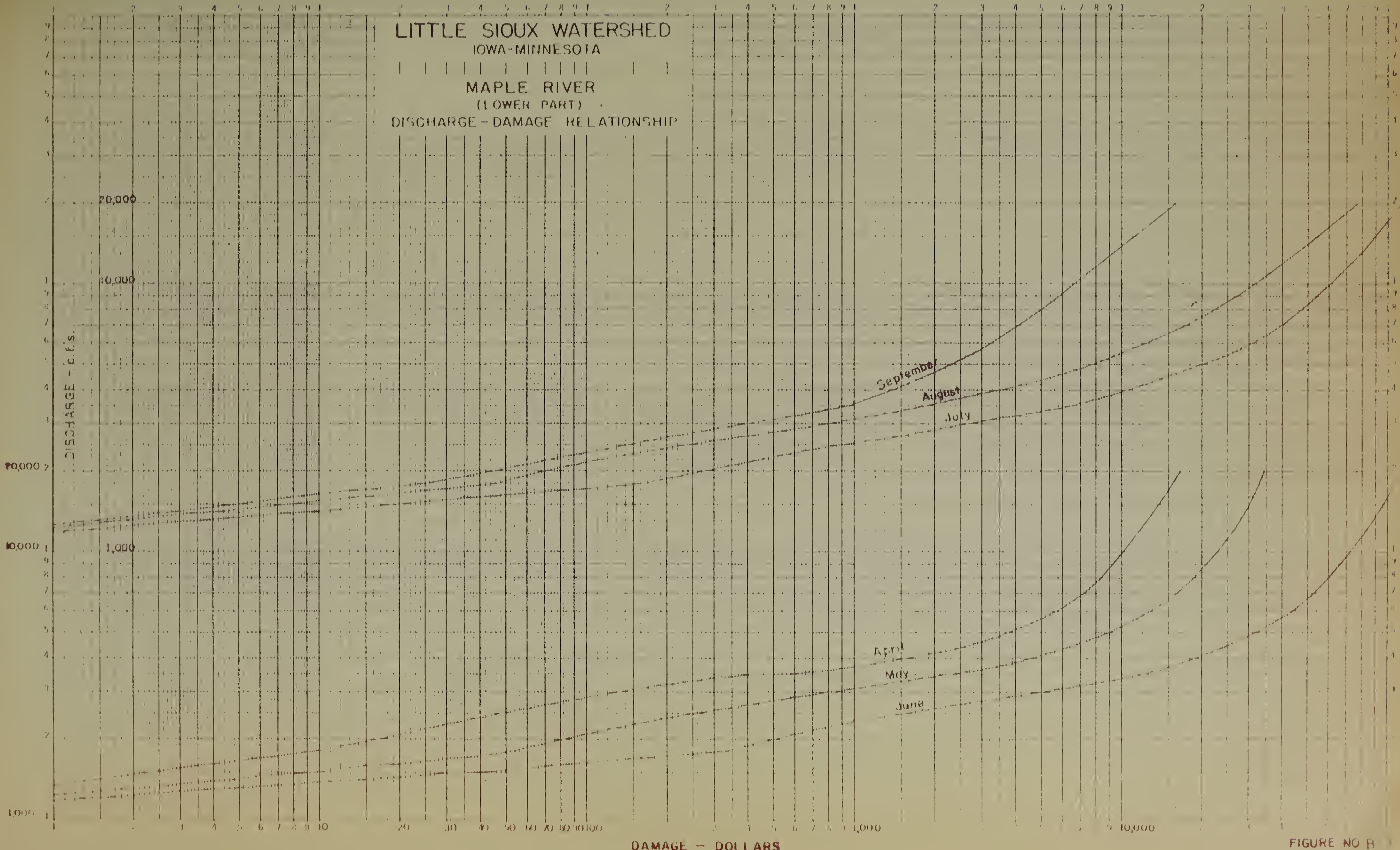


FIGURE NO 8

CROP AND PASTURE

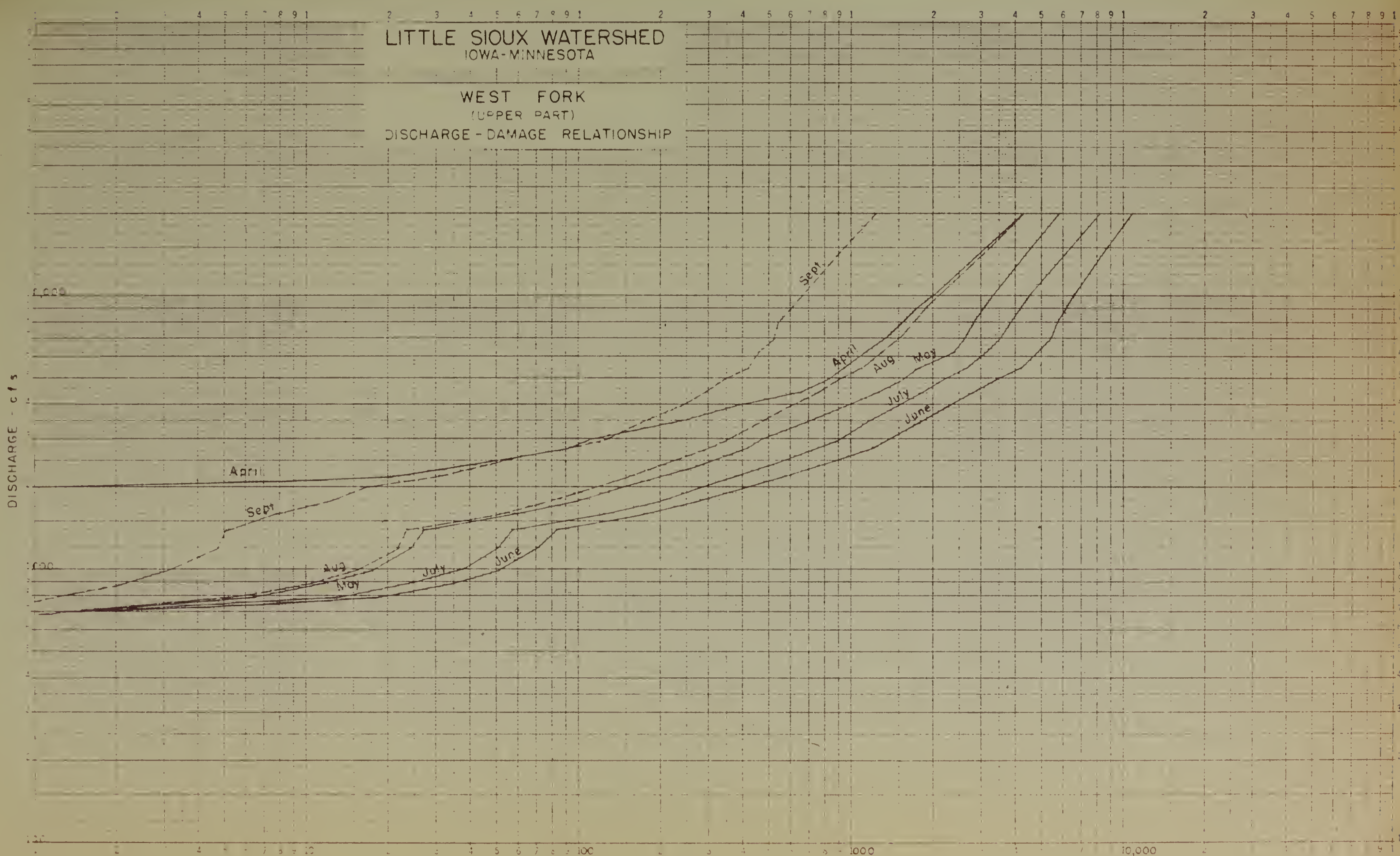


FIGURE NO. B-7

CROP AND PASTURE

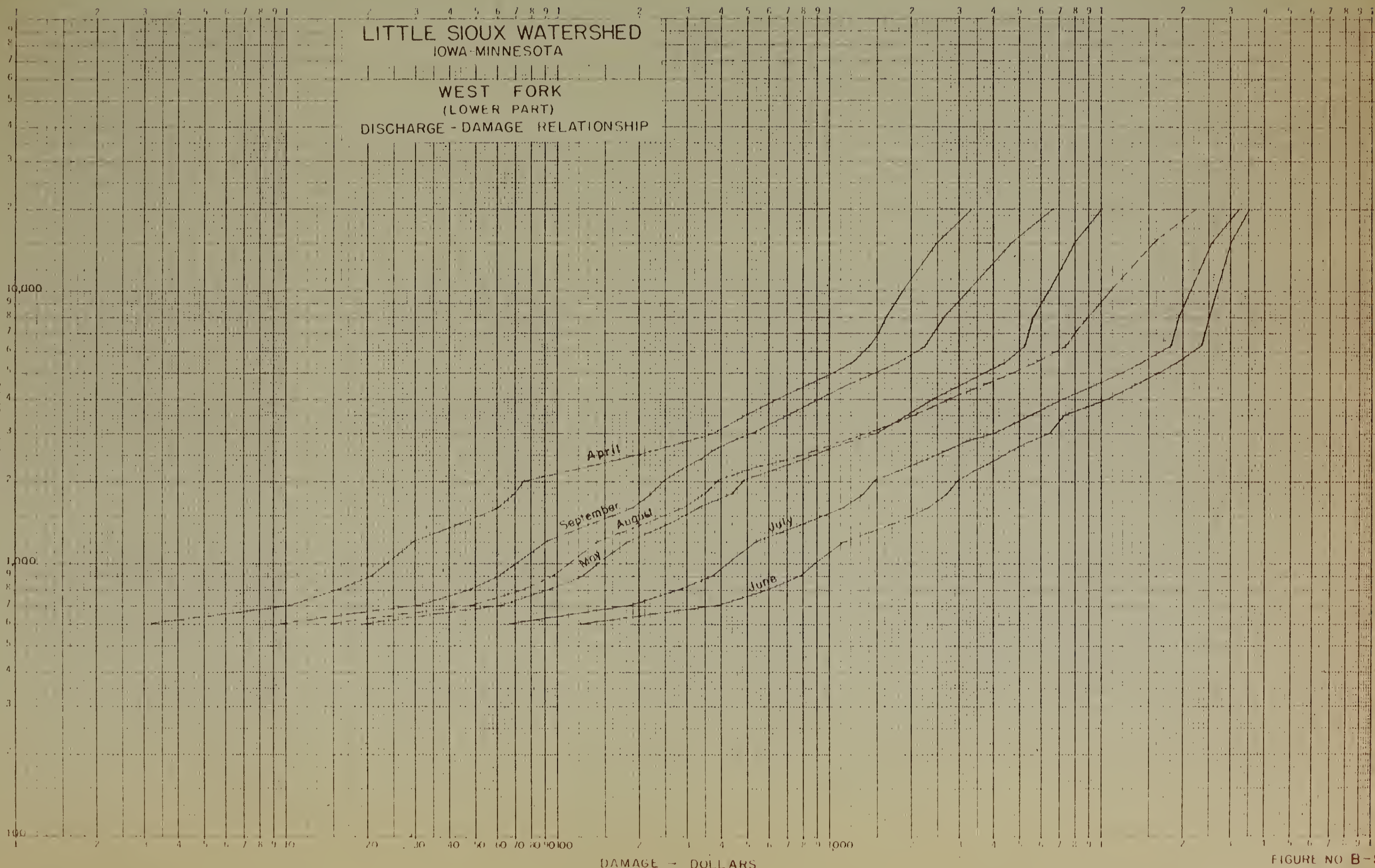


FIGURE NO B-9

CROP AND PASTURE

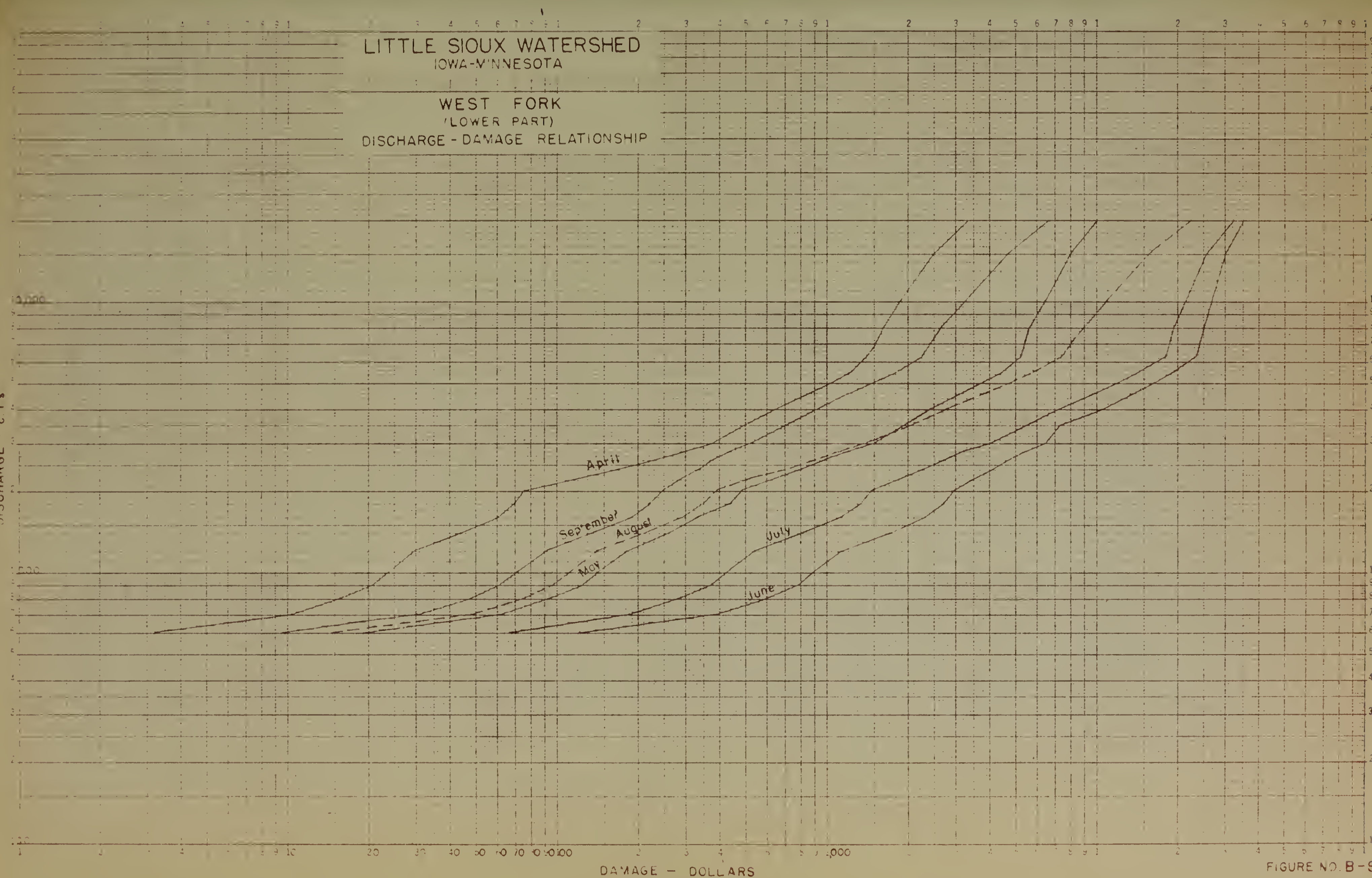


FIGURE NO. B-8

CROP AND PASTURE

TABLE B-13. CROP AND PASTURE DAMAGES BY MONTHS, WEST FORK (Lower Part)

		DAMAGE											
Dis-charge	Acres flood-ed	Per flood	Per acre	Per flood	Per acre	Per flood	Per acre	Per flood	Per acre	Per flood	Per acre	Per flood	Pe acre
		April		May		June		July		August		September	
600	45	3.18	.07	19.01	.42	120.27	2.66	56.73	1.26	14.91	.33	9.58	.21
700	146	10.22	*.07	61.32	*.42	388.36	*2.66	183.96	*1.26	48.18	*.33	30.66	*.21
800	225	15.75	*.07	94.50	*.42	598.50	*2.66	283.50	*1.26	74.25	*.33	47.25	*.21
900	295	20.65	*.07	123.90	*.42	784.70	*2.66	371.70	*1.26	97.35	*.33	61.95	*.21
1000	337	23.59	*.07	141.54	*.42	896.42	*2.66	424.60	*1.26	111.21	*.33	70.77	*.21
1200	430	29.88	.07	181.67	.42	1144.70	2.66	541.30	1.26	142.32	.33	91.78	.21
1400	640	44.80	*.07	268.80	*.42	1715.20	*2.68	819.20	*1.28	211.20	*.33	134.40	*.21
1600	860	60.20	*.07	369.80	*.43	2322.00	*2.70	1126.60	*1.31	292.40	*.34	189.20	*.22
1800	1000	70.00	*.07	440.00	*.44	2720.00	*2.72	1330.00	*1.33	350.00	*.35	220.00	*.22
2000	1083	75.06	.07	484.91	.45	2963.35	2.74	1470.40	1.36	391.92	.36	249.21	.23
2200	1150	115.00	*.10	632.50	*.55	3473.00	*3.02	1840.00	*1.60	540.50	*.47	287.50	*.25
2400	1250	162.50	*.13	812.50	*.65	4125.00	*3.30	2300.00	*1.84	725.00	*.58	337.50	*.27
2600	1310	222.70	*.17	982.50	*.75	4716.00	*3.60	2724.80	*2.08	903.90	*.69	379.90	*.29
2800	1400	294.00	*.21	1190.00	*.85	5460.00	*3.90	3262.00	*3.90	1120.00	*.80	434.00	*.31
3000	1560	376.93	.24	1491.07	.96	6544.93	4.20	4019.83	2.58	1424.57	.91	525.20	.34
3500	1720	498.80	*.29	1926.40	*1.12	8393.60	*4.88	5486.80	*3.19	2029.60	*1.18	705.20	*.41
4000	1910	649.40	*.34	2444.80	*1.28	10619.60	*5.56	7258.00	*3.80	2769.50	*1.45	916.80	*.48
4500	2150	838.50	*.39	3096.00	*1.44	13416.00	*6.24	9481.50	*4.41	3719.50	*1.73	1182.50	*.55
5000	2370	1042.80	*.44	3792.00	*1.60	16400.40	*6.92	11897.40	*5.02	4763.70	*2.01	1493.10	*.63
5500	2550	1249.50	*.49	4488.00	*1.76	19380.00	*7.60	14356.50	*5.63	5839.50	*2.29	1810.50	*.71
6300	2750	1439.08	.52	5280.83	1.92	23850.51	8.64	18178.26	6.61	7488.08	2.72	2262.67	.82
7000	2800	1512.00	*.54	5488.00	*1.96	24332.00	*8.69	18816.00	*6.72	8092.00	*2.89	2436.00	*.87
8000	2860	1630.20	*.57	5777.20	*2.02	25053.60	*8.76	19648.00	*6.87	8951.80	*3.13	2688.40	*.94
9000	2950	1770.00	*.60	6136.00	*2.08	26048.50	*8.83	20709.00	*7.02	9971.00	*3.38	2979.50	*1.01
10000	3000	1890.00	*.63	6420.00	*2.14	26700.00	*8.90	21540.00	*7.18	10890.00	*3.63	3070.00	*1.09
15000	3250	2502.50	*.77	7930.00	*2.44	30062.50	*9.25	25870.00	*7.96	15762.50	*4.85	4712.50	*1.45
20000	3659	3383.86	.92	10063.19	2.75	35171.75	9.61	32017.18	8.75	22212.83	6.07	6669.34	1.82

* Figures - interpolated values.

SECTION III - CORRECTION FOR SEQUENCE EFFECTS

With the list of flood peaks for each watershed under present and recommended conditions and with discharge-damage curves, it was possible to determine the total damage caused by each flood for the evaluation period of record if, at the time of each flood, conditions had not been modified by preceding floods. However, when two or more floods occurred during the same growing season the effect of this sequence of events precluded the determination of flood damage for each flood solely by the use of discharge-damage curves due to the successive modification of the prime damage by preceding floods.

The procedure used to determine the flood damage by a series of floods in sequence was as follows. The damage caused by the discharge of the first flood was read directly from the discharge-damage curve. The damages by the second, third, and fourth floods, if they occurred close enough together to result in damage that would be modified by the effect of the preceding floods, were reduced from that shown on the discharge-damage curve by the following formula:

$$\text{Damage (dollars)} = D_2 - \frac{D_2 \, D_1 \, (1-c)}{d_1 \, A_1}$$

in which:

A_1 = area flooded during the first flood (acres)

D_1 = the damage done on area A_1 during the first flood (dollars)

D_2 = the damage that would have been done by the second flood if the first flood had not occurred (dollars)

d_1 = the damage per acre if the entire crop was destroyed at the time of the first flood. It may also be considered as the value of the crop per acre at the time of the first flood (dollars)

c = a replant factor which is the ratio of the value of the replant crop to the value of the original crop at the time of the first flood.

In this formula it is assumed that each acre damaged will be replanted if the season permits, and consideration is given to the replant value of crops by seasons, the percentage of various crops on the flooded area, and the change in crop values as the season progresses.

As an example of the application of this formula, the damage calculations for the lower zone on West Fork for the year 1912 are shown below:

Table B-14 Damage Calculations — West Fork

Date	Peak discharge c.f.s.	Acres flooded: Upper zone	Acres flooded: Lower zone	Damage: Upper zone	Damage: Lower zone
5-26-12	680	0	140	0	49
6-20-12	1760	580	975	260	2662
8-16-12	2720	1280	1370	274	972

As the second flood is larger than the first, the formula applies to the land flooded the second time; and full damage must be figured on the balance.

The damage of a June flood of 1760 cfs is \$2670. The damage of a June flood of 680 cfs is \$325. Therefore, the damage done on the area which has not been flooded is \$2670 - \$325 or \$2345.

D_2 = the damage of a 680 cfs flood in June = \$325

D_1 = the damage of a 680 cfs flood in May = \$49

d_1 = \$4.06 from Table B-15

c = .715 from Table B-16

A_1 = 140 as shown in Table B-14

$$D_2 - \frac{D_2 D_1}{d_1 A_1}(1-c) = 325 - \frac{325 \times 49}{4.06 \times 140}(1 - .715) =$$

$$325 - \frac{15900}{568} \times .285 = 325 - 8 = \$317$$

The total damage during the June flood of 1760 cfs would be 2345 plus 317 or \$2662 as shown in Table B-14.

The next flood occurred in August and had a peak discharge of 2720 cfs. The damage of a 2720 cfs flood in August is \$1050. The damage of a 1760 cfs flood in August is \$342. The damage on the area which has not been flooded is \$1050 - \$342 or \$708.

D_2 = the damage of 1760 cfs flood in August = \$342

D_1 = the damage of a 1760 cfs flood in June = \$2662 from previous calculations

d_1 = \$10.43—from Table B-15

c = .132—from Table B-16

A = 975 as shown in Table B-14

$$D_2 - \frac{D_2\ D_1}{d_1\ A_1}(1-C) = 342 - \frac{342 \times 2662}{10.43 \times 975}(1 - .132)$$

$$342 - \frac{91600}{10180} \times .868 = 342 - 78 = \$264$$

\$264 + 708 = \$972 = the total damage during the 2720 cfs flood in August.

TABLE B-15. DAMAGE PER ACRE "d" BY MONTHS FOR 100% DESTRUCTION - WEST FORK

Land Use in Per-cent	Crop	April: Damage per acre 100% de-stroyed	April: Damage per acre basis	May: Damage per acre 100% de-stroyed	May: Damage per acre basis	June: Damage per acre 100% de-stroyed	June: Damage per acre basis	July: Damage per acre 100% de-stroyed	July: Damage per acre basis	August: Damage per acre 100% de-stroyed	August: Damage per acre basis
LOWER PART											
35.2	Corn	1.00	.35	6.52	2.30	22.95	8.08	25.44	8.95	25.44	8.95
8.9	Grain	4.22	.38	4.89	.44	11.41	1.02	13.84	1.23	8.18	.73
5.0	Hay	1.26	.06	7.17	.30	10.83	.54	10.45	.52	9.59	.48
35.0	Pasture	3.00	1.05	2.75	.96	2.25	.79	1.75	.61	1.25	.44
15.9	Waste	0	-	0	-		-	0	-	0	-
100.0			1.84		4.06		10.43		11.31		10.60
UPPER PART											
7.7	Corn	1.00	.08	6.52	.50	22.95	1.77	25.44	1.96	25.44	1.96
3.3	Grain	4.22	.14	4.89	.16	11.41	.38	13.84	.46	8.18	.27
0	Hay	1.26	0	7.17	-	10.83	-	10.45	0	9.59	0
86.9	Pasture	3.00	2.61	2.75	2.39	2.25	1.96	1.75	1.52	1.25	1.09
2.1	Waste	0	-	0	-	0	-	0	-	0	-
100.0			2.83		3.05		4.11		3.94		3.32

TABLE B-16. REPLANT FACTORS - WEST FORK - LOWER REACH

Crop	Percent distri-bution	Value original crop	Total value 100 acres	Value of replant crop	Total value 100 acres	Replant Factors
April						
Corn	35.2	26.52	933.50	26.52	933.50	$\frac{1125.30}{1257.80}$ = .895
Grain	8.9	15.41	137.15	12.32	109.65	
Hay	5.0	16.43	82.15	16.43	82.15	
Pasture	35.0	3.00	105.00	0	0	
Waste	15.9	0	0	0	0	
			1257.80		1125.30	
May						
Corn	35.2	26.52	933.50	21.06	741.31	$\frac{893.24}{1249.05}$ = .715
Grain	8.9	15.41	137.15	10.93	97.28	
Hay	5.0	16.43	82.15	10.93	54.65	
Pasture	35.0	2.75	96.25	0	0	
Waste	15.9	0	0	0	0	
			1249.05		893.24	
June						
Corn	35.2	26.52	933.50	3.28	115.46	$\frac{161.05}{1221.55}$ = .132
Grain	8.9	15.41	137.15	3.28	29.19	
Hay	5.0	16.43	82.15	3.28	16.40	
Pasture	35.0	2.25	78.75	0	0	
Waste	15.9	0	0	0	0	
			1221.55		161.05	
July						
Corn	35.2	26.52	933.50	0	0	$\frac{0}{1214.05}$ = .0
Grain	8.9	15.41	137.15	0	0	
Hay	5.0	16.43	82.15	0	0	
Pasture	35.0	1.75	61.25	0	0	
Waste	15.9	0	0	0	0	
			1214.05		0	

TABLE B-17. CALCULATION OF AVERAGE ANNUAL DAMAGE - PRESENT LAND USE, LITTLE SIOUX MAIN STEM

Date	Peak Dis-charge cfs	Flood Damages Reach 2	Reach 3	Reach 4
6-3-18	5429	18900	9900	81000
4-22-19	3773	1610	300	5650
5-29-19	3196	1864	244	12342
6-12-19	11214	49465	25471	138270
6-28-19	6288	9880	5380	32850
7-14-19	8698	16730	10045	62040
8-13-19	1865	454	0	1347
5-13-20	5209	6600	4100	22000
6-7-20	5816	17690	9460	73400
7-11-20	4213	5220	2260	20000
5-27-21	4035	3750	1400	17500
4-16-22	1928	200	0	660
4-5-24	1782	138	0	390
6-29-24	5502	18959	10000	80876
8-15-24	4559	3000	1340	10500
6-4-25	2295	2150	0	13000
6-17-25	1981	857	0	2770
4-30-29	2463	550	0	1660
6-17-29	2861	4114	261	32486
5-13-30	1834	370	0	1350
6-13-30	3144	5282	730	46042
7-17-30	2861	1860	137	9360
4-1-32	4087	2000	520	6100
4-21-32	6707	5342	2977	8994
5-6-32	2599	1123	15	5436
5-26-32	5188	5883	3681	20202
4-2-37	1740	140	0	340
5-31-37	7650	12989	7650	29977
6-19-37	7965	29310	14950	98500
8-19-37	6896	7800	3760	18100
5-5-38	2389	950	0	3850
6-13-38	3554	6027	1100	50230
7-8-38	2882	2042	137	10000
8-8-38	1656	310	0	657
9-21-38	7640	3895	1893	7347
6-7-40	2788	4050	175	29000
8-26-40	4873	6650	3193	26700
		258154	121079	980926
				121079
				258154
		Average annual damage		15/1360159 = $ 90673

TABLE B-18. CALCULATION OF AVERAGE ANNUAL DAMAGE UNDER REMEDIAL PROGRAM, LITTLE SIOUX MAIN STEM

Date	Peak Dis-charge cfs	Flood Damages Reach 2	Reach 3	Reach 4
6-3-18	5000	18200	8500	75000
4-22-19	3300	1500	155	4870
5-29-19	2870	1699	93	7951
6-12-19	10450	49059	24946	126080
6-28-19	5870	9710	5100	30000
7-14-19	8200	16110	8620	60400
8-13-19	1500	395	0	0
5-13-20	4700	6400	3250	20000
6-7-20	5360	16810	8590	68000
7-11-20	3730	4930	1467	18700
5-27-21	3550	3500	820	15500
4-16-22	1550	165	0	0
4-5-24	1400	123	0	0
6-29-24	5025	18564	8600	76000
8-15-24	4050	2870	1115	9500
6-4-25	2000	1800	0	7500
6-17-25	1560	817	0	1230
4-30-29	2100	480	0	900
6-17-29	2500	3802	68	18709
5-13-30	1440	315	0	0
6-13-30	2800	4900	270	28500
7-17-30	2500	1670	37	5300
4-1-32	3640	1870	300	5480
4-21-32	6280	5254	2689	8469
5-6-32	2250	1050	0	3105
5-26-32	4730	5759	3084	18995
4-2-37	1420	113	0	0
5-31-37	7230	12742	7250	27400
6-19-37	7550	29090	14160	96500
8-19-37	6480	7560	3500	17800
5-5-38	2050	830	0	2250
6-13-38	2930	5597	580	37000
7-8-38	2500	1670	46	5720
8-8-38	1250	250	0	0
9-21-38	7230	3825	1787	6956
6-7-40	2350	3680	52	16500
8-26-40	4410	6355	2498	25370
		249464	107577	845685
				107577
				249464
		Average annual damage		15/1202726 =$ 80182

TABLE B-19. CALCULATION OF AVERAGE ANNUAL DAMAGE - PRESENT LAND USE, MAPLE RIVER MAIN STEM

Date	Peak discharge cfs	Acres Flooded		Damage	
		Upper	Lower	Upper	Lower
6-3-18	3350	1390	3580	$ 3250	9800
4-22-19	2380	650	860	25	35
5-29-19	2040	360	355	49	88
6-12-19	8230	4920	9150	16493	61860
6-28-19	3930	1860	4480	4763	12340
7-14-19	6090	3330	7300	5035	13250
8-13-19	1200	25	12	11	1
5-13-20	3220	1290	3350	585	1350
6-7-20	3620	1620	4000	3870	13377
7-11-20	2620	840	1570	774	1113
5-27-21	2550	783	1340	210	290
4-16-22	1230	26	17	3	0
4-5-24	1120	16	5	2	0
6-29-24	3390	1420	3620	3300	10000
8-15-24	2860	1030	2350	405	509
6-4-25	1490	43	58	110	25
6-17-25	1270	28	21	49	3
4-30-29	1570	52	66	6	3
6-17-29	1820	140	145	269	340
5-13-30	1150	21	8	8	1
6-13-30	2000	310	310	399	480
7-17-30	1820	140	145	137	138
4-1-32	2560	785	1350	33	52
4-21-32	4260	2090	4950	410	2299
5-6-32	1650	70	80	31	23
5-26-32	3220	1290	3350	556	1307
4-2-37	1110	15	4	2	0
5-31-37	5090	2630	6150	2550	9200
6-19-37	5410	2870	6530	8557	34660
8-19-37	4440	2220	5230	1043	3390
5-5-38	1500	44	59	21	9
6-13-38	2120	430	435	515	640
7-8-38	1820	140	145	135	143
8-8-38	1050	10	2	6	0
9-21-38	5090	2630	6150	617	2394
6-7-40	1800	125	125	250	325
8-26-40	3020	1140	2830	288	831
		36783	80132	54767	180276
					54767
		Average annual damage			15/235043 = $15670

TABLE B-20. CALCULATION OF AVERAGE ANNUAL DAMAGE UNDER REMEDIAL PROGRAM, MAPLE RIVER MAIN STEM

Date	Peak Discharge cfs	Acres Flooded Upper	Acres Flooded Lower	Damage Upper	Damage Lower
6-3-18	2620	835	1550	1300	2150
4-22-19	1810	135	135	10	10
5-29-19	1560	51	66	23	12
6-12-19	6800	3830	8000	13194	52000
6-28-19	5160	1240	3170	2076	5770
7-14-19	4980	2570	6000	3792	7925
8-13-19	930	0	0	0	0
5-13-20	2510	750	1200	200	270
6-7-20	2870	1030	2380	1823	3774
7-11-20	2020	335	335	248	250
5-27-21	1970	265	265	64	76
4-16-22	960	0	0	0	0
4-5-24	850	0	0	0	0
6-29-24	2660	860	1680	1350	2300
8-15-24	2190	490	510	122	89
6-4-25	1150	21	8	48	1
6-17-25	970	0	0	0	0
4-30-29	1200	25	12	2	0
6-17-29	1420	36	50	96	15
5-13-30	880	0	0	0	0
6-13-30	1530	47	63	127	40
7-17-30	1420	36	50	42	9
4-1-32	1970	265	265	13	15
4-21-32	3420	1460	3680	130	350
5-6-32	1300	29	27	12	2
5-26-32	2510	750	1200	200	270
4-2-37	840	0	0	0	0
5-31-37	4030	1940	4630	1350	4800
6-19-37	4330	2150	5100	5760	22100
8-19-37	3520	1550	3840	742	1418
5-5-38	1170	21	9	9	1
6-13-38	1600	59	72	148	75
7-8-38	1420	36	50	58	8
8-8-38	800	0	0	0	0
9-21-38	4030	1940	4630	400	1430
6-7-40	1410	35	48	94	14
8-26-40	2330	620	760	204	155
		23411	49785	33637	105329
					33637
		Average Annual Damage			15/138966 = $ 9264

TABLE B-21. CALCULATION OF AVERAGE ANNUAL DAMAGE - PRESENT LAND USE, WEST FORK MAIN STEM

Date	Peak Discharge cfs	Acres Flooded		Damage	
		Upper	Lower	Upper	Lower
5-26-12	900	70	295	$ 12	$ 124
6-20-12	1930	790	1070	365	2877
8-16-12	3280	1433	1620	404	1655
5-2-13	1275	152	510	25	210
7-22-13	900	70	295	24	361
6-10-14	1180	140	410	69	1100
9-9-14	3570	1495	1748	184	720
5-25-15	1510	240	770	44	310
6-5-15	1670	490	900	203	2412
7-17-15	3000	1374	1500	896	3732
7-4-16	2600	1230	1350	730	2725
8-6-16	1180	140	410	17	124
9-9-16	750	0	185	0	37
4-17-17	560	0	0	0	0
8-6-17	510	0	0	0	0
5-17-18	580	0	0	0	0
6-4-18	1770	590	980	260	2700
5-6-19	790	0	210	0	90
6-9-19	1940	800	1080	370	2883
7-3-19	2160	990	1133	329	1433
5-11-20	1070	112	365	20	156
6-30-20	1460	200	710	103	1871
7-13-20	1590	360	840	108	921
6-14-21	870	58	270	29	740
8-31-21	790	0	210	0	55
9-2-21	1875	730	1045	14	226
7-28-22	3300	1435	1633	1075	4900
8-20-22	1730	555	960	64	291
6-17-23	920	75	320	37	810
7-12-23	1080	120	370	39	394
8-6-23	540	0	0	0	0
9-30-23	1830	670	1020	13	218
6-27-24	1580	370	830	160	2300
7-15-24	1350	162	570	50	581
5-19-25	2060	920	1112	460	530
6-2-25	3020	1380	1510	1434	6097
6-16-25	970	90	323	40	661
5-9-26	1790	610	980	96	440
7-23-26	2050	910	1128	2994	1538
9-17-26	2970	1365	1482	118	479
5-20-27	630	0	85	0	28
8-15-27	530	0	0	0	0
		20126	30229	10786	46729
					10786

Average annual damage 16/57515 = $ 3595

TABLE B-22. CALCULATION OF AVERAGE ANNUAL DAMAGE UNDER REMEDIAL PROGRAM, WEST FORK MAIN STEM

Date	Peak Dis-charge cfs	Acres Flooded		Damage	
		Upper	Lower	Upper	Lower
5-26-12	680	0	140	$ 0	$ 49
6-20-12	1760	580	975	260	2662
8-16-12	2720	1280	1370	273	972
5-2-13	1125	125	387	22	167
7-22-13	630	0	90	0	88
6-10-14	980	93	327	47	870
9-9-14	2890	1350	1448	108	460
5-25-15	1300	155	535	25	222
6-5-15	1460	200	715	101	1859
7-17-15	2550	1210	1293	592	2471
7-4-16	2190	1010	1173	373	1810
8-6-16	940	84	310	11	91
9-9-16	600	0	45	0	9
4-17-17	350	0	0	0	0
8-6-17	430	0	0	0	0
5-17-18	370	0	0	0	0
6-4-18	1400	170	640	83	1720
5-6-19	630	0	90	0	28
6-9-19	1675	480	915	215	2496
7-3-19	1825	660	1015	197	1093
5-11-20	810	40	240	7	98
6-30-20	1280	132	515	76	1352
7-13-20	1420	180	670	51	718
6-14-21	710	0	160	0	415
8-31-21	600	0	45	0	12
9-2-21	1625	420	880	8	189
7-28-22	2940	1360	1470	870	3830
8-20-22	1330	160	575	21	164
6-17-23	720	0	170	0	430
7-12-23	850	52	262	18	288
8-6-23	410	0	0	0	0
9-30-23	1560	310	820	7	175
6-27-24	1260	150	480	66	1300
7-15-24	1110	125	380	39	383
5-19-25	1900	755	1060	122	467
6-2-25	2560	1210	1327	929	4512
6-16-25	720	0	170	0	335
5-9-26	1375	165	610	27	260
7-23-26	1840	685	1025	218	1346
9-17-26	2590	1225	1335	59	349
5-20-27	420	0	0	0	0
8-15-27	370	0	0	0	0
		14366	23662	4825	33690
					4825
		Average annual damage			16/38515 = $ 2407

TABLE B-23. CALCULATION OF AVERAGE ANNUAL DAMAGE, ELLIOTT CREEK MAIN STEM

	Present Land Use			Under Remedial Program		
Date	Peak Discharge cfs	Acres flooded	Damage	Peak Discharge cfs	Acres flooded	Damage
5-26-12	620	104	119	450	30	13
6-20-12	1360	360	2736	1180	313	2379
8-16-12	2330	730	576	1970	555	467
5-2-13	870	230	267	720	130	145
7-22-13	620	104	348	400	5	3
6-10-14	820	190	1340	660	111	835
9-9-14	2675	853	600	2000	565	361
6-5-15	1150	310	2350	980	277	2085
7-17-15	2225	685	2652	1830	522	1772
7-4-16	1910	544	2330	1570	445	1730
8-6-16	820	190	150	650	110	84
9-9-16	515	62	39	370	0	0
6-4-18	1300	333	2530	960	273	2060
5-6-19	520	65	75	390	3	1
6-9-19	1380	375	2822	1140	309	2350
7-3-19	1580	450	1180	1170	311	685
5-11-20	745	138	158	525	67	78
6-30-20	1010	282	2072	870	230	1671
7-13-20	1090	302	685	960	273	659
6-14-21	590	96	710	470	40	110
9-2-21	1320	342	203	1120	307	197
7-29-22	2410	765	3500	2115	623	2750
8-20-22	1270	328	256	890	253	194
6-17-23	630	107	790	455	32	51
7-12-23	745	137	342	570	85	302
9-30-23	1280	330	203	1070	295	183
6-27-24	1110	306	2320	850	215	1560
7-15-24	925	268	555	750	140	289
5-19-25	1455	404	470	1310	337	390
6-2-25	2235	690	5221	1785	510	3754
6-16-25	670	115	494	480	47	152
5-9-26	1310	339	390	930	269	308
7-23-26	1445	400	1553	1270	327	1224
9-17-26	2200	675	480	1820	518	360
5-20-27	420	13	4	275	0	0
		11622	40520		8527	29202

16/40520 = $2533 Average annual damage - present

16/29202 = $1825 Average annual damage - under remedial program.

SECTION IV - CALCULATION OF CROP AND PASTURE DAMAGES

By the procedures and data previously described, flood damages were calculated for each flood in an evaluation series established for each of the sub-watersheds. The derivation of these evaluation series is explained in Appendix B.

By entering the curves of Figures B-2 to B-9 with the peak discharges for each flood in the evaluation series, and making necessary corrections for the effect of previous floods on damageable values, the damages of Tables B-17 to B-23 were calculated. It will be noted that in addition to damages for the present condition of the watershed, the damages that will occur under the remedial program are included in this set of tables. This was done to facilitate comparison of damages under treated and untreated conditions.

SECTION V - DAMAGE TO LAND BY MAJOR GULLIES

To determine the damage that will be done in the future by the major gullies it was necessary to predict the approximate rate of growth of the damaged area (area destroyed plus area depreciated in value) of these gullies. This was done by making a study of 29 sample gullies chosen at random. Of these, eleven were classed as "major" gullies and for each of these the following information was obtained:

1 - Area contributing run-off to the gully system.

2 - Area of land destroyed, that is, actually removed by the gully system.

3 - Area of land forced into a less renumerative use by action of the gully and thus depreciated in value.

4 - Value of undepreciated lands.

5 - Value of depreciated lands.

6 - Approximate age of the gully system.

These data are summarized in Table B-24.

The gullies in the Little Sioux watersheds are comparatively young and for this reason the form of the relation between age and effect could not be derived therefrom. But from the life history of older gullies in other parts of the United States it is known that, in general, such systems grow at an accelerating rate in their early life, throwing off new and rapidly advancing laterals at frequent intervals. As the system ages, however, the areas contributing run-off to the ever increasing number of tributary gullies become smaller and smaller and eventually the rate of growth decelerates. An equation often used to express the characteristics of simple physical phenomena of this nature is:

$$\text{Cumulative effect} = \frac{1}{1 + C e^{-kt}}$$

It was recognized that the growth of a gully system might not follow such a simple expression in the latter portion of the cycle of planation. But since the data available covered such a limited range it was felt that the estimate would not be improved by use of a more complicated equation. Moreover since it was intended to discount all damages to their present worth it was evident that large errors in the predicted damages during the latter years of the cycle would have but a negligible effect upon monetary damages. Both of these considerations led to the selection of the foregoing equation to express the growth characteristics of an average major gully in this watershed.

The data given in Table B-24 were used to evaluate the constants in the expression given and the following equation was derived for the growth of an average gully system:

$$\text{Percent of contributing area damaged at end of t years} = \frac{100}{1 + 1000e^{-.07t}}$$

The area damaged each year is given by:

$$\text{Percent of contributing area damaged annually} = \frac{70\ e^{-.07t}}{\left[1 + 1000e^{-.07t}\right]^2}$$

By use of these equations it was possible to plot the curves of Figure 2 of the body of this report.

To obtain the monetary value of the damage done by each of the sample gullies the areas damaged annually were multiplied by the present worth factor for an interest rate of 3.5 percent. A set of such curves was derived for gullies of various assumed ages. By determining the area under these curves the "present equivalent" of the area damaged was determined. These values were used to prepare another curve showing the present equivalent of the area damaged for gullies of any present age. From this latter curve the present equivalent of the area to be damaged in the future was determined for each sample gully; using as the present age of each, the age corresponding to the area now damaged. Thus the discounted damage for each sample was determined in terms of area, assuming that the future growth of that sample would follow the equation for an average system.

To obtain the monetary value of the future damage for each sample gully the present equivalent of the area damaged was multiplied by the reduction in value of land depreciated in value because of the proximity of the gully. The calculation of this damage is shown by Table B-25.

It is obvious that the actual damage will exceed that derived in Table B-25, as a part of the area "damaged" is actually destroyed and will have no remaining value. But since the value of depreciated land is small it was obvious that the additional damage experienced through its complete destruction would not greatly increase the damages already calculated. For this reason, and to insure a conservative estimate of total damages, this additional damage was omitted from the estimate used in evaluation. Also omitted were the expenditures required to construct and maintain 1/ numerous bridges over the gullies.

1/ A study of a number of such bridges indicated that the average annual maintenance on a single bridge amounts to $208.

TABLE B-24. DATA ON SAMPLES OF MAJOR GULLIES

Sample No.	Contributing Area	Area Destroyed	Area Damaged (Destroyed) plus Depreciated	Value of Unaffected Lands	Value of Depreciated Lands	Approximate Age of Gully
	acres	acres	acres	$ per acre	$ per acre	years
		Samples in Lower Sampling Zone				
1	1638	57.8	57.8	85	10	40
4	3277	107.5	126.7	85	10	60
5	794	56.9	120.3	80	10	50
6	2534	103.0	131.8	75	10	60
9	7424	54.8	79.8	75	10	38
10	704	16.9	16.9	90	10	
11	5408	330.4	871.4	60	5	
13	2368	403.0	640.0	60	5	
		Samples in Intermediate Sampling Zone				About 60 years
17	1901	63.8	181.6	75	5	
19	2227	92.2	214.4	75	5	
32	1402	73.2	169.9	75	5	

TABLE B-25. CALCULATION OF FUTURE MONETARY DAMAGES ATTRIBUTABLE TO DEPRECIATION IN VALUE OF LANDS ADJACENT TO MAJOR GULLIES

Sample No.	Equivalent Age of Gully 1/	Present Equivalent of Area to be damaged in the Future 2/		Decrease in Value of Land Damaged	Present Value of Future Depreciation Damage
	Years	Percent	Acres	$	$
		Samples in Lower Sampling Zone			
1	53	23.3	382	75	28,650
4	54	23.7	777	75	58,275
5	74	35.0	278	70	19,460
6	58	25.7	651	65	42,315
9	33	14.8	1099	65	71,435
10	47	20.1	142	80	11,360
11	75	35.2	1904	55	104,720
13	85	36.0	852	55	46,860
		Samples in Intermediate Sampling Zone			
17	66	29.7	565	70	39,550
19	66	29.7	661	70	46,270
32	70	32.3	453	70	31,710

Damage in lower sampling zone:
Total for samples - $383,075. Damage per acre of contributing area $14.51.
Total damage in zone - 235,520 acres @ $14.51 = $3,417,395.

Damage in intermediate sampling zone:
Total for samples - 117,530. Damage per acre of contributing area $8.33.
Total damage in zone - 293,120 acres @ $8.33 = $2,441,220.

Damage in upper sampling zone:
No damage from major gullies.

Total damage attributable to expected future depreciation in land values (present value) $5,858,615.
Average annual equivalent (3.5% interest) $205,052.

1/ Age corresponding to area depreciated in value at present time as shown by curve for average gully.

2/ Derived by discounting percent of area to be depreciated each year in the future to its present value at 3.5% interest rate and summing.

SECTION VI - DAMAGE TO DRAINAGE DISTRICTS

The ditches that conduct the floods of the Little Sioux watershed across the drainage districts on the Missouri River alluvial plain are rapidly filled with sediment and must be periodically dredged. A study of the cost of dredging operations in these districts, and of other steps taken to keep the ditches open, indicated that the average annual damage attributable to ditch filling is $42,093.

In Section V of Appendix A it was stated that 21.52 percent of the material deposited in these ditches came from the major gullies, 43.75 percent from the lands of Division A and the remaining 34.73 percent from Division B. Assuming that the damage caused is proportional to the contribution of sediment the cost of ditch maintenance was opportioned as follows:

	DIVISION A	DIVISION B	TOTAL
Sheet and ordinary gully erosion	18,417	14,618	33,035
Major gullies	-	9,058	9,058
	18,417	23,676	42,093

SECTION VII - SUMMARY OF DAMAGES

The damages determined by the procedure outlined in the preceding Sections are summarized in Tables B-26 and B-27. The former gives the damages determined by Divisions and the latter the damages necessarily determined by subwatersheds.

Table B-26 SUMMARY OF DAMAGES DETERMINED BY DIVISIONS

Average Annual Values

DIVISION A
(Zones 2 and 3)

Damage to land by major gullies	None
Damage caused by filling of drainage ditches	18,147
Total	18,147

DIVISION B
(Zone 4)

Damage to land by major gullies	205,052
Damaged caused by filling of drainage ditches	23,673
Total	228,725

Table B-27

SUMMARY OF DAMAGES DETERMINED BY SUBWATERSHEDS

Average Annual Values

LITTLE SIOUX SUBWATERSHED

Damages in Zones 2, 3 and 4

Damage to crops and pastures		
On the main stem (Table B-17)	$90,673	
On tributaries	14,700	
Total crop and pasture damage		105,373
Damage to fences, highways and railroads		
On the main stem	3,410	
On tributaries	24,150	
Total fence, highway and railroad damage		27,560

Damages in Zone 5

Damage to crops and pastures		15,583

MAPLE RIVER SUBWATERSHED

Damages in Zones 2, 3 and 4

Damage to crops and pastures		
On the main stem (Table B-19)	15,670	
On tributaries	5,500	
Total crop and pasture damage		21,170
Damage to fences, highways and railroads		
On the main stem	624	
On tributaries	14,600	
Total fence, highway and railroad damage		15,224

Damages in Zone 5

Damage to crops and pastures		11,481

WEST FORK SUBWATERSHED

Damages in Zones 2, 3 and 4

Damage to crops and pastures		
On the main stem of West Fork proper (Table B-21)	3,595	
On tributaries of " " "	4,900	
On the main stem of Elliott Creek (Table B-23)	2,533	
On tributaries of " "	500	
On other tributaries in the watershed 1/	2,779	
Total crop and pasture damage		14,307
Damage to fences, highways and railroads		
On the main stem of West Fork proper	1,523	
On tributaries of " " "	10,940	
On the main stem of Elliott Creek	309	
On tributaries of " "	1,960	
On other tributaries in the subwatershed 2/	8,695	
Total fence, highway and railroad damage		23,427

Damages in Zone 5

Damage to crops and pasture		54,849

1/ Estimated by applying tributary damage per unit area on West Fork tributaries to remainder of watershed

2/ Estimated by applying tributary damage per unit area on Elliott Creek (total) to remainder of watershed.

APPENDIX C

REMEDIAL PROGRAM

CONTENTS

SECTION I - FARM LAND TREATMENT PROGRAM

Program For Open Land

General Procedure:

Each sample farm was planned on the ground by a planning technician. Using the conservation survey of the farm and the land use capabilities recommendations (See Table C-1), the planner determined for each part of the farm the land use and the supplementary practices required. In planning the use of supplementary practices such as terracing and contour cultivation, the topography of the land had to be considered. In some cases the topography was found to be so irregular that terracing and contour cultivation were not considered practical and permanent hay or pasture was planned for those areas. The aim was to plan a program for the farm which would be permanently effective and economically practical. The plans aim to secure land uses and practices which will produce flood reductions and at the same time promote efficient farming systems without waste of the soil resource. Cropping practices and the use of supplementary erosion control practices such as terracing, contour cultivation, contour furrowing, contour fencing, gully control, pasture management, liming, fertilizing, and the proper utilization of barnyard manure and crop residue, together with the adjustments of the farm management program are used. The recommendations of the Iowa State experiment station relative to liming, fertilizing, seeding mixtures, seeding rates, pasture improvement, and other cultural practices were adopted for the sample farms. Contacts were made with local people such as county agricultural agents, farmers, land use planning committees, business men, and Soil Conservation Service project and camp personnel in order to obtain additional information relative to land use problems and effective remedial measures.

Present Land Use: Present land use was recorded on one copy of a conservation survey map of the sample farm in order that the map would indicate the extent and location of the following:

Clean tilled
Small grain
Rotation hay and pasture
Permanent hay
Permanent pasture, tame, poor
Permanent pasture, tame, good
Permanent pasture, native, poor
Permanent pasture, native, fair
Permanent pasture, native, good
Timber
Idle
Farmsteads
Roads

IOWA LAND USE CAPABILITIES (Upland Loess & Residual Soils)

CLASSES	I	II	IIIa	IIIb	IV	V
Land Use & Supporting Practices - Terrace		C - C - C - M	C - C - O - M - M	C - C - O - M - M - M	(C - O - M - M - M - M	Timber or Pasture
Contour, Contour with Buffers, or Contour Strip Crop		C - C - O - M - M C - C - O - M ****	C - C - O - M - M - M	C - O - M - M	(Permanent Meadow	
No Practices	C - C - O - M C - C - (O-Sw.Cl.)***	0-3% C-C-O-M-M 3-7% C-O-M-M	0-3% C-O-M-M 3-7% C-O-M-M-M 7-12% C-O-M-M-M-M	0-3% C-O-M-M-M 3-7% C-O-M-M-M-M 7-16% Permanent Meadow	Timber or Pasture	

	No.	Soil Types	Productivity Rating 10 Groups	Productivity Rating 5 Groups	I Slope	I Erosion	II Slope	II Erosion	IIIa Slope	IIIa Erosion	IIIb Slope	IIIb Erosion	IV Slope	IV Erosion	V Slope	V Erosion
UPLAND LOESS SOILS	9	Marshall silt loam	1	1	0-2%	All conditions	2-8%	1,2	2-8%	22,3	8-14%	22,3	14-18%	22,3	18-20%	22,3
	120	Tama silt loam	1	1					8-14%	1,2	14-18%	1,2	18-20%	1,2	20% & over	All conditions
	228	Afton silty clay loam	3/6	2												
	227	Marcus silt loam	1	1												
	30	Muscatine silt loam	1	1												
	34	Muscatine silty clay loam	1/6	1/3	0-34*	All conditions							0-3%	All conditions		
	64	Grundy silt loam	1	1												
	115	Grundy silty clay loam	1/6	1/3	0-2%*	All conditions	2-7%	1,2	2-7%	22	2-7%	3	0-2%	All conditions		
	68	Grundy clay loam	2/7	1/3												
	211	Edina silt loam	4	2			0-2%*	All conditions					0-2%	All conditions		
	154	Scott silt loam	4/10	2/5												
	257	Marshall silt loam (light colored phase)	5	3			0-7%	1,2	0-7%	22,3	7-12%	22,3	12-16%	22,3	16-20%	22,3
	11	Knox silt loam	8	4					7-12%	1,2	12-16%	1,2	16-20%	1,2	20% & over	All conditions
	80	Clinton silt loam	5	3												
	122	Clinton fine sandy loam	6	3												
	178	Clinton very fine sandy loam	6	3												
	163	Fayette silt loam	5	3												
	250	Fayette very fine sandy loam	6	3												
	259	Tame fine sandy loam	5	3					0-7%	1,2	0-7%	22,3	7-12%	22,3	12% & over	All conditions
	261	Weller silt loam	5	3							7-12%	1,2				
	66	Putman silt loam	7	4							0-3%	All conditions				
	158	Clinton sand	9	5												
	203	Clinton fine sand	9	5												
	141	Clinton loamy fine sand	9	5												
	242	Fayette sand	9	5									0% & over	All conditions		
	208	Fayette fine sand	9	5												
	33	Knox fine sand	10	5												
	67	Marion silt loam	8	4												
	8	Tama sand	9	5												
	145	Tama loamy fine sand	8	4												
UPLAND RESIDUAL SOILS	210	Boone fine sandy loam	7	4												
	223	Dodgeville loam	7	4												
	204	Dodgeville silt loam	7	4												
	222	Dodgeville sandy loam	8	4					0-7%	1,2	0-7%	22,3	7-12%	22,3	12% & over	All conditions
	205	Rossville silt loam	6	3							7-12%	1,2				
	237	Sogn loam	6	3												
	154	Sogn clay loam	6	3												
	155	Sogn silt loam	6	3												
	212	Crawford loam	10	5												
	22	Crawford silt loam	10	5												
	183	Dubuque silt loam	10	5												
	184	Cascanade loam	10	5												
	156	Hagerstown silt loam	10	5												
	155	Sogn stony silt loam	10	5												
	157	Union silt loam	10	5												
	116	Union silty clay loam	10	5												
	73	Union stony loam	10	5												

(All gullied areas with a 7 symbol, where the rotation together with supporting practices will not control same, should be retired to permanent grassed waterways.)
(All gullied areas with the following symbols should be retired to timber, wildlife, or permanent grass: - (7), 7V, 8, (8), 8V, 9.)
* Adequate Drainage
*** To be used only on overflow land.
**** To be used only on Wabash & Lamoure - Judson Complex.

I O W A   L A N D   U S E   C A P A B I L I T I E S   (Upland Drift Soils)

CLASSES				I		II		IIIa		IIIb		IV		V	
Land Use & Supporting Practices - Terrace						C - C - C - M		C - C - O - M - M		C - C - O - M - M - M		(C - O - M - M - M - M (Permanent Meadow		Timber or Pasture	
Contour, Contour with Buffers or Contour Strip Crop						C - C - O - M - M C - C - O - M ****		C - C - O - M - M - M		C - O - M - M					
No Practices				C - C - O - M C - C - (O-Sw.Cl.)***		0-3% 3-7%	C-C-O-M-M C-O-M-M	0-3% 3-7% 7-12%	C-O-M-M C-O-M-M-M C-O-M-M-M-M	0-3% 3-7% 7-16%	C-O-M-M-M C-O-M-M-M-M Permanent Meadow	Timber or Pasture			
No.	Soil Types	Productivity Rating 10 Groups	Productivity Rating 5 Groups	Slope	Erosion	Slope	Erosion	Slope	Erosion	Slope	Erosion	Slope	Erosion	Slope	Erosion
84	Clyde silt loam	4/10	2/5												
85	Clyde silty clay loam	4/10	2/5												
198	Floyd silt loam	3	2/4												
55	Webster loam	1/5	1/3	0-3%*	All conditions							0-3%	All conditions		
113	Webster silt loam	1/5	1/3												
107	Webster silty clay loam	1/8	1/4												
56	Webster clay loam	1/10	1/4												
1	Carrington loam	1	1												
83	Carrington silt loam	1	1	0-2%	All conditions	2-7%	1,2	2-7%	22,3	7-12%	22,3	12-16%	All conditions	16% & over	All conditions
138	Clarion loam	1	1					7-12%	1,2						
169	Clarion silt loam	1	1												
3	Carrington sandy loam	5	3					0-7%	2,22,3	7-12%	22,3	12-16%	1,2	12-16%	22,3
4	Carrington fine sandy loam	5	3											16% & over	All conditions
134	Carrington very fine sandy loam	5	3												
253	Clarion sandy loam	5	3					7-12%	1,2						
149	Clarion fine sandy loam	5	3												
79	Shebly loam	7	4												
93	Shelby silt loam	6	3												
174	Dickinson loam	7	4					0-2%	All conditions	2-7%	1,2	2-7%	22,3	7-12%	22,3
199	Dickinson sandy loam	8	4									7-12%	1,2	12% & over	All conditions
175	Dickinson fine sandy loam	8	4												
167	Conover silt loam	7	4												
65	Lindley loam	8	4							0-7%	1,2	0-7%	22,3	7-11%	22,3
32	Lindley silt loam	8	4									7-11%	1,2	11% & over	All conditions
221	Shelby sandy loam	8	4												
92	Shelby fine sandy loam	8	4												
59	Carrington gravelly loam	9	5												
119	Carrington sand	9	5												
86	Carrington fine sand	9	5												
240	Carrington loamy fine sand	9	5												
148	Clarion fine sand	9	5												
147	Clarion loam (gravelly subsoil phase)	9	5												
238	Dickinson loamy sand	9	5												
249	Dickinson loamy fine sand	9	5												
226	Lakeville sandy loam	8	4											0% & over	All conditions
161	Lindley sandy loam	9	5												
136	Lindley fine sandy loam	9	5												
137	Lindley very fine sandy loam	9	5												
239	Lindley sand	10	5												
135	Lindley fine sand	10	5												
173	Pierce loam	10	5												
191	Pierce sandy loam	10	5												
170	Pierce fine sandy loam	10	5												
78	Rough stony land	10	5												
196	Shelby gravelly sand loam	9	5												
94	Shelby loamy fine sand	9	5												
241	Thurston loam	8	4												
162	Thurston sandy loam	9	5												
123	Thurston loamy sand	10	5												

UPLAND DRIFT SOILS

(All gullied areas with a 7 symbol, where the rotation together with supporting practices will not control same, should be retired to permanent grassed waterways)
(All gullied areas with the following symbols should be retired to timber, wildlife, or permanent grass: - (7), 7V, 8, (8), 8V, 9.)
* Adequate Drainage.
** Sufficiently drained and free from damage to crops by overflow.
*** To be used only on overflow land.

I O W A   L A N D   U S E   C A P A B I L I T I E S (Bottomland Soils)

CLASSES				I		II		IIIa		IIIb		IV		V	
Land Use & Supporting Practices - Terrace						C - C - C - M		C - C - O - M - M		C - C - O - M - M - M		(C - O - M - M - M - M (Permanent Meadow		Timber or Pasture	
Contour, Contour with Buffers or Contour Strip Crop						C - C - O - M - M C - C - O - M ****		C - C - O - M - M - M		C - O - M - M					
No Practices				C - C - O - M C - C - (O-Sw.Cl.)***		0-3% C-C-O-M-M 3-7% C-O-M-M		0-3% C-O-M-M 3-7% C-O-M-M-M 7-12% C-O-M-M-M-M		0-3% C-O-M-M-M 3-7% C-O-M-M-M-M 7-16% Permanent Meadow		Timber or Pasture			
No.	Soil Types	Productivity Rating 10 Groups	5 Groups	Slope	Erosion	Slope	Erosion	Slope	Erosion	Slope	Erosion	Slope	Erosion	Slope	Erosion
106	Cass silt loam	6/10	3/5												
51	Cass silty clay loam	6/10	3/5												
216	Cass silty clay	6/10	3/5												
71	Genesee silt loam	6/10	3/5												
112	Lamoure loam	5/10	3/5												
153	Lamoure silt loam	5/10	3/5												
111	Lamoure silty clay loam	6/10	3/5	** 0-2%	+									0-2%	+
185	Lamoure clay loam	6/10	3/5												
215	Lamoure silty clay	6/10	3/5												
195	Ray silt loam	6/10	3/5												
140	Rogers silt loam	6/10	3/5												
49	Wabash loam	5/10	3/5												
26	Wabash silt loam	5/10	3/5												
48	Wabash silty clay loam	6/10	3/5												
63	Wabash clay loam	6/10	3/5												
27	Wabash silty clay	6/10	3/5												
77	Lamoure-Judson Complex	3	2												
26a	Wabash-Judson Complex	3	2			2-6%	+								
18	Cass loam	7/10	4/5												
165	Cass clay	7/10	4/5												
19	Cass sandy loam	7/10	4/5								+				
130	Cass fine sandy loam	7/10	4/5												
217	Cass very fine sandy loam	7/10	4/5												
182	Genesee silty clay loam	7/10	4/5												
117	Genesee fine sandy loam	7/10	4/5												
70	Genesee very fine sandy loam	7/10	4/5												
166	Lamoure clay	7/10	4/5			** 0-2%	+							0-2%	+
91	Sarpy loam	7/10	4/5												
89	Sarpy silt loam	7/10	4/5												
144	Sarpy silty clay loam	8/10	4/5												
220	Sarpy silty clay	8/10	4/5												
72	Wabash clay	7/10	4/5												
52	Wabash sandy loam	8/10	4/5												
62	Wabash fine sandy loam	7/10	4/5												
192	Wabash very fine sandy loam	7/10	4/5												
266	Wabash silt loam (Gray subsoil phase)	8/10	4/5												
50	Cass sand	9/10	5												
54	Marsh	10	5												
20	Meadow	10	5												
53	Riverwash	10	5												
90	Sarpy sand	9/10	4/5												
102	Sarpy fine sandy loam	9/10	4/5											0-2%	+
28	Sarpy very fine sandy loam	9/10	4/5												
160	Sarpy sand	9/10	4/5												
133	Sarpy fine sand	9/10	4/5												
29	Sarpy very fine sand	9/10	4/5												
103	Sarpy loamy sand	9/10	4/5												
181	Wabash stony silt loam	8/10	4/5												

(All gullied areas with a 7 symbol, where the rotation together with supporting practices will not control same, should be retired to permanent grassed waterways)
(All gullied areas with the following symbols should be retired to timber, wildlife, or permanent grass: - (7), 7V, 8, (8), 8V, 9.)
* Adequate Drainage.
** Sufficiently drained and free from damage to crops by overflow.
*** To be used only on overflow land.
**** To be used only on Wabash & Lamoure-Judson Complex.

I O W A   L A N D   U S E   C A P A B I L I T I E S (Terrace Soils)

CLASSES	I	II	IIIa	IIIb	IV	V
Land Use & Supporting Practices - Terrace		0 - C - C - M	C - C - O - M - M	C - C - O - M - M - M	(C - O - M - M - M - M (Permanent Meadow	Timber or Pasture
Contour, Contour with Bullers or Contour Strip Crop		C - O - O - M - M C - C - O - M ****	O - C - O - M - M - M	C - O - M - M		
No Practices	C - C - O - M C - C - (O-Sw.Cl.)***	0-3% C-C-O-M-M 3-7% C-O-M-M	0-3% C-O-M-M 3-7% C-O-M-M-M 7-12% C-O-M-M-M-M	0-3% C-O-M-M-M 3-7% O-O-M-M-M-M 7-16% Permanent Meadow	Timber or pasture	

TERRACE SOILS

No.	Soil Types	Productivity Rating 10 Groups	Productivity Rating 5 Groups	I Slope	I Erosion	II Slope	II Erosion	IIIa Slope	IIIa Erosion	IIIb Slope	IIIb Erosion	IV Slope	IV Erosion	V Slope	V Erosion
12	Bremer Loam	2/5	1/3												
68	Bremer silt loam	2/5	1/3												
43	Bremer silty clay loam	4/10	2/5												
17	Fargo loam	2/7	1/4												
152	Fargo silt loam	2/7	1/4												
109	Fargo silty clay loam	3/10	2/5	*											
61	Hancock loam	2	1	**											
23	Hancock silt loam	2	1	0-3%	All conditions	3-6%	All conditions	5-12%	1,2,22	6-12%	3	0-3%	All conditions		
24	Hancock silty clay	4/10	2/5							12-18%	1,2,22	12-18%	3		
190	Judson loam	2	1									18% & over	All conditions		
131	Judson silt loam	1	1												
251	Judson fine sandy loam	4	2												
60	Waukesha loam	1	1												
75	Waukesha silt loam	1	1												
127	Waukesha sandy loam	4	2												
128	Waukesha fine sandy loam	4	2												
264	Benoit loam	5/10	3/5												
201	Benoit silt loam	5/10	3/5												
258	Benoit silty clay loam	5/10	3/5												
246	Bertrand loam	6	3												
193	Bertrand silt loam	5	3												
244	Bertrand sandy loam	8	3												
44	Bremer clay	5/10	3												
15	Bremer fine sandy loam	5	3												
38	Buckner loam	8	3												
36	Buckner silt loam	6	3												
105	Chariton silt loam	5	3												
100	Davenport silt loam	5	3			*									
101	Davenport silt clay loam	6	3			0-3%	All conditions	3-7%	1,2,22	3-7%	3	0-3%	All conditions		
160	Davenport clay loam	6	3							7% & over	All conditions				
99	Davenport sandy loam	8	3												
255	Fargo clay	5/10	3												
214	Hancock fine sandy loam	5	3												
139	Hancock very fine sandy loam	5	3												
81	Jackson silt loam	6	3												
188	Millsdale loam	5	3												
209	Millsdale silt loam	5	3												
238	Millsdale fine sandy loam	8	3												
108	O'Neill loam	5	3												
205	O'Neill silt loam	5	3												
76	Sioux loam	5	3												
229	Sioux silt loam	5	3												
40	Buckner sandy loam	8	4												
45	Buckner fine sandy loam	8	4												
89	Buckner very fine sandy loam	6	4												
42	Calhoun silt loam	7	4					*							
179	Judson loamy sand	8	4					0-3%	All conditions	3-7%	1,2,22	0-3%	All conditions		
231	Lacrosse loam	7	4									3-7%	3		
126	O'Neill sandy loam	7	4									7% & over	All conditions		
110	O'Neill find sandy loam	7	4												
172	O'Neill loamy fine sand	8	4												
14	Sioux sandy loam	7	4												
171	Sioux fine sandy loam	7	4												
47	Buckner coarse sandy loam	9	5												
82	Buckner gravelly sandy loam	9	5												
41	Buckner sand	10	5												
159	Buckner loamy sand	10	5												
46	Buckner fine sand	10	5												
168	Buckner loamy fine sand	9	5												
39	Buckner coarse sand	10	5												
225	Hancock fine sand	10	5									0% & over	All conditions		
125	O'Neill coarse sandy loam	9	5												
124	O'Neill sand	10	5												
146	O'Neill fine sand	10	5												
247	O'Neill loamy fine sand	10	5												
25	Osgood very fine sand	10	5												
16	Plainfield loam	5	5												
98	Plainfield sandy loam	9	5												
97	Plainfield fine sandy loam	9	5												
194	Plainfield sand	10	5												
118	Plainfield loamy fine sand	9	5												
245	Sparta fine sand	10	5												

(All gullied areas with a 7 symbol, where the rotation together with supporting practices will not control same, should be retired to permanent grassed waterways.)
(All gullied areas with the following symbols should be retired to timber, wildlife, or permanent grass: - (7), 7V, 8, (8), 8V, 9.)

* Adequate Drainage.

** Sufficiently drained and free from damage to crops by overflow.

*** To be used only on overflow land.

**** To be used only on Wabash & Lamoure-Judson Complex.

Recommended Land Use: The recommended land use and supplementary practices were recorded on another copy of the conservation survey map as follows:

Crop rotation (no practices needed)
Crop rotation (contour cultivated)
Crop rotation (terraced)
Permanent hay
Permanent pasture, tame, good
Permanent pasture, tame, renovated
Permanent pasture, tame, contour furrowed
Permanent pasture, native, poor
Permanent pasture, native, fair
Permanent pasture, native, good
Grazed woodland
Protected woodland
Protected woodland to be planted
Farmsteads
Roads

Proposed pasture renovation, contour furrowing, liming, fertilizing, gully control, and fence rearrangement were also recorded on the conservation survey map.

Summary of Data: The proposed land use changes and conservation practices are shown by major delineations in Tables C-2 and C-3, and by Divisions in Tables 3 and 4 of the body of the Report.

Crop Rotations: One of the basic essentials for the maintenance of a high productivity level of the soil is that crop rotations be carefully planned to include sufficient legumes and grasses. The most intensive rotation used in the plans for the sample farms was corn, corn, oats, meadow and the most extensive rotation used was corn, oats, meadow, meadow, meadow.

Organic matter, so necessary, in the soil can be maintained by the use of the proper crop rotations along with other soil management and erosion control practices. Soils containing large amounts of organic matter absorb more water and are less erodible than those deficient in organic matter.

Under the farm land treatment program, winter cover crops, such as winter rye or sweet clover, will be used to protect land which has been in clean tilled crops during the fall and winter months. Such cover crops are valuable for feed and serve a dual purpose of furnishing late fall and early spring pasture as well as affording protection against erosion by wind and water during the season of their growth.

Table C-4 shows a proposed method of initiating the rotation of crops.

Getting Stands of Legumes and Grasses: Satisfactory stands of legumes and grasses are necessary to the success of the program. Recommendations

Table C-2 - Present land use and recommended land use by major physical delineations (in percent) of acreage

	9-B-1		9-B-2		9-C-2&3		11-C-2		11-C-3		11-D-1		11-D-2		11-D-3		150-C&D-1&2	
	1/	2/	1/	2/														
Total acreage	328064	328064	443200	443200	135040	135040	52992	52992	141760	141760	10176	10176	71488	71488	113792	113792	112832	112832
Clean tilled	47.35	35.65	34.62	28.29	38.80	24.87	40.47	18.61	40.52	17.70	19.02	4.63	28.24	11.28	32.97	10.56	28.48	18.02
Small Grain	27.08	17.82	30.28	15.36	31.69	13.34	31.62	10.61	24.81	10.74	3.09	2.35	16.67	5.94	24.10	6.38	24.44	10.26
Rotation hay and pasture	5.64	28.76	10.28	33.50	8.88	31.35	14.62	43.27	14.68	28.15	2.95	4.31	11.18	12.08	15.81	16.60	3.81	19.59
Permanent hay	4.06	3.43	3.04	1.98	2.63	8.22	.00	.00	3.31	16.90	2.41	12.19	2.40	15.92	1.84	21.89	1.59	5.98
Poor tame pasture	3.93	.00	5.50	.00	7.88	.00	3.71	.00	7.42	.00	4.41	.00	9.39	.13	7.09	.00	16.98	3.79
Good tame pasture	6.32	8.80	9.43	14.92	3.13	15.27	.15	19.70	1.20	18.72	.19	11.48	.20	22.70	.60	32.12	11.25	29.43
Poor native pasture	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	12.51	.00	10.30	.00	.39	.00	2.57	.00
Fair native pasture	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.66	9.60	3.86	8.04	.15	.15	.00	.00
Good native pasture	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.05	11.33	1.99	9.47	.00	.00	.00	.00
Grazed woodland	.25	.00	.42	.00	.00	.00	1.09	.00	.63	.00	37.69	10.53	8.11	.58	5.47	1.44	6.30	1.85
Protected woodland	.00	.27	.00	.58	.00	1.30	.00	2.31	.00	2.58	.00	27.52	.00	10.06	.00	6.76	.00	7.01
Unproductive land	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.14	4.29	.37	.37	.00	.00	.00	.00
Idle land	.11	.00	.92	.00	1.37	.00	2.50	.00	2.27	.00	2.68	.00	3.62	.00	7.10	.00	.37	.00
Farmsteads	2.75	2.76	3.10	2.96	2.77	2.80	3.13	2.79	2.60	2.65	1.29	.84	1.74	1.50	2.34	1.96	2.12	1.98
Roads	2.51	2.51	2.41	2.41	2.85	2.85	2.71	2.71	2.56	2.56	.93	.93	1.93	1.93	2.16	2.16	2.09	2.09
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1/ Present   2/ Recommended

LITTLE SIOUX WATERSHED
Iowa - Minnesota

Table C-3 - Recommended supplementary soil conservation practices (in acres per 100 and units per 100 acres)

Practice	Unit	9-B-1	9-B-2	9-C-2&3	11-C-2	11-C-3	11-D-1	11-D-2	11-D-3	50-C&D-1&2
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Total acreage	acre	328064	443200	135040	52992	141760	10176	71488	113792	112832
Terracing		13.9	9.0	22.9	21.7	16.7	.0	6.9	8.9	3.2
Contour cultivation	"	50.6	47.0	45.5	33.1	35.3	9.1	18.6	21.5	23.9
Contour furrowing	"	.0	.0	.0	2.6	.0	.4	6.9	6.7	.0
Tree planting(gully)	"	.02	.03	1.08	1.17	1.58	.28	.83	1.06	.81
Tree planting(other)	"	.0	.13	.22	.19	.37	.30	1.84	1.91	1.78
Gully control -----	"	1.44	1.66	1.63	1.51	1.51	.7	1.4	.94	.7
Gully control xxxxx	"	.0	.09	.20	.47	.19	.0	.11	.07	.12
Gully control lllll	"	.0	.02	.14	.11	.06	.05	.06	.04	.02
		Per 100A	Per 100A	Per 100A	Per 100A	Per 100A	Per 100A	Per 100A	Per 100A	Per 100A
Fence to be built	rod	16	48	100	149	137	172	232	151	122
Sloping & sodding	each	0	0	.1	.12	.02	0	0	0	.04
Diversion dike	feet	0	15	17	86	46	21	63	85	63
Channel straightening	"	0	0	0	0	5	0	0	11	0
Streambank protection	"	0	0	0	0	5	0	0	0	0
Earth dike	each	0	0	0	0	.12	0	0	0	.02

LITTLE SIOUX WATERSHED
Iowa - Minnesota

Table C-4 - Proposed installation of crop rotations by fields

Rotations	Crop	Legume and grass seeding
CCOMMM		
Field 1	Corn	Sweet clover 10 * at last cultivation
2	Corn	Rye as winter cover crop
3	Oats	Alfalfa 10, Brome grass 8
4	Oats	Red Clover 4, alfalfa 4, alsike 2, timothy 4
5	Oats	Sweet clover 10, timothy 4
6	Oats	Sweet clover 10
COMMM		
Field 1	Corn	Rye as winter cover crop
2	Oats	Alfalfa 10, Brome 8
3	Oats	Red clover 4, alfalfa 4, alsike 2, timothy 4
4	Oats	Sweet clover 10, timothy 4
5	Oats	Sweet clover 10
CCOMM		
Field 1	Corn	Sweet clover 10
2	Corn	Rye as winter cover crop
3	Oats	Red clover 4, alfalfa 4, alsike 2, timothy 4
4	Oats	Sweet clover 10, timothy 4
5	Oats	Sweet clover 10
COMM		
Field 1	Corn	Rye as winter cover crop
2	Oats	Red clover 4, alfalfa 4, alsike 2, timothy 4
3	Oats	Sweet clover 10, timothy 4
4	Oats	Sweet clover 10
CCOM		
Field 1	Corn	Sweet clover 10
2	Corn	Rye as winter cover crop
3	Oats	Red clover 8, timothy 4
4	Oats	Sweet clover 10

* Pounds per acre.

of the state experiment station should be carefully followed. In the past much seed and effort has been lost because of lack of attention to proper soil management practices.

The use of adapted varieties, proper seeding rates, use of lime and fertilizers when needed, inoculation of legumes, proper time of seeding, proper preparation of seedbed, proper rate of seeding and utilization of nurse crop, weed control, firming of the seedbed, top dressing with manure, and the use of surface mulch are all important and will be given attention in seeding legumes and grasses.

The rates of seeding used in the farm planning of the program are given below:

Crop	Years to be left seeded down	Pounds of seed per acre
Rotation hay	3	Alfalfa 10, brome grass 8.
Rotation hay	2	Red clover 4, alfalfa 4, alsike 2, timothy 4.
Rotation hay	1	Red clover 8, timothy 4.
Rotation pasture	1	Sweet clover 10, timothy 4.
Permanent hay	7	Alfalfa 10, brome grass 8.
Permanent pasture to be established	10	Alfalfa 4, sweet clover 4, brome 6, timothy 4.
Permanent pasture renovation	10	Sweet clover 6, brome grass 8.
Green manure	-	Sweet clover 10.

Liming and Fertilizing: The following rates of application of lime and phosphate fertilizer (0-20-0) were used in developing farm plans; Bulletins S-117 "Fertilizer for Iowa" and S-63 "Soil Management for Iowa Cropland and Pasture" being used as a basis for these rates.

	Lime Once every 12 years	Phosphate (0-20-0) Once in each rotation
Marshall silt loam	1.5 tons	200 pounds
Marshall silt loam (brown phase)	- -	200 "
Marcus silt loam) Webster silt loam) Webster silty clay loam)	- -	150 "
Clarion loam) Clarion silty clay loam)	1.0	150 "

	Lime Once every 12 years	Phosphate (0-20-0) Once in each rotation
Clarion fine sandy loam) Clarion, steep phase)	1.0	200 pounds
Dickson fine sand	2.0	200 "
Knox silt loam	- -	200 "
Waukesha silt loam	2.0	150 "
Wabash-Judson silt loam	2.0	150 "

In the rotation the phosphate is to be applied preceding the small grain crop. For seeding permanent pasture or meadow the phosphate amount should be raised 50 pounds per acre. In actual practice, liming on the individual farm would be a matter of making tests of each field or parts of each field to determine the lime needs.

Improvement of Tame Pastures: Overgrazing, together with the series of dry years from 1934 to 1936, have caused serious damage to a large proportion of the tame permanent pastures in the watershed.

The farm land treatment program includes a carefully planned pasture program to provide for sufficient feed of high quality for as many months of the year as possible. This requires the use of adapted legumes and grasses, maintenance of the soil in a high state of productivity, and proper grazing management such as controlled grazing, rotational grazing and use of supplementary pastures.

Native Grass Pasture Improvement: The native grass pastures are located chiefly in the steep bluff area adjacent to the Missouri River Flood Plain. Continued overgrazing has weakened many of the native grass stands resulting in poor vegetative cover and increased run-off and erosion. Lack of moisture and low fertility of the soil are two important factors influencing vegetation in this bluff section.

The native grasses are very drought resistant and will survive extreme dry weather. However, they will not stand overgrazing and will be killed out if overgrazing continues. A combination of the dry years of 1934 and 1936 and continuous overgrazing has caused severe damage on native grass pastures in this area.

In planning the sample farms in that part of the watershed, considerable variation in the character of the bluffland was observed. Consequently, it was thought advisable to divide the land into categories. The native grass pastures were classified as good, fair, or poor. South and southwest barren slopes were classified as unproductive land. Those areas where timber production was considered to be the proper land use, were designated for woodlots.

The program planned proposes that grazing management be adopted as the principal means of improving the native grass pastures. Such management includes deferred grazing, alternate resting and grazing, and the use of sweet clover. Experimental results obtained by both the Iowa State Experiment Station and the Nebraska State Experiment Station show that thin, weakened native grass pastures will respond satisfactorily to proper grazing management.

A problem that exists on certain parts of the native grass land is the encroachment of brush such as corral berry and sumac. It is believed that overgrazing has been the cause of the spread of this brush and that under proper grazing management it will be held in check. Where practical the brush should be kept cut down.

Supplementary Soil Conservation Practices -

The farm land treatment program requires the use of supplementary practices such as terracing, contour cultivation, establishment of grassed waterways, other gully control measures, contour furrows, and contour fencing. The combination of these practices with proper land use, applications of lime and commercial fertilizers, and the careful conservation of barnyard manure and crop residues will effectively reduce soil erosion and run-off.

Terracing: Terracing will be used as one of the principal control measures. Since the use of contour strip cropping is limited in this area because of increased damage from hot winds and insects, terracing has to be used to a large extent in order to effectively reduce soil erosion.

In general, slopes up to 12 percent will be terraced provided they are uniform enough in topography and soil conditions permit. Ordinarily only the upper part of the slope will be terraced. Level broad base terraces with open ends will be used except where soil conditions make necessary the use of variable graded type.

In practically all cases grassed waterways will be used as terrace outlets.

Contour Cultivation: Contour planting of corn has been one of the most effective erosion control measures in this area.

Contour listing of corn land will be practiced and the use of the basin lister will be encouraged. Advantages of listing corn are impoundage of water and easier control of weeds.

All contour cultivation will be as nearly on the exact contour as practical. In contour cultivated fields buffer strips of permanent hay may be necessary to serve as guide lines for contour operations. Also on irregular slopes these strips can include correction areas which otherwise would have to be in short rows. Headlands of permanent hay can be established at the ends of the fields for turning of farm machinery. Buffer strips and headlands should be of sufficient width to

allow for harvesting of the hay crop from them.

Contour Fencing: Removal of up and down hill fences and the establishment of field boundaries and fences on the contour will be necessary as part of the establishment of the farm land treatment program on the farms.

Gully Control Measures: Wherever possible gullies will be controlled by establishing good vegetative cover. Proper land use and the use of conservation practices in the drainage area also serve as gully control measures and aid much in the stabilizing of existing gullies by vegetation.

Some gullies have advanced to such a stage that other measures such as concrete flumes, drop inlets, earth dams and diversion dikes must be used as a measure of control. These structures have been included in the major gully control program.

In the farm land treatment program gullies will be controlled by the following means:

Grassed Waterways: Because of lack of attention to seeding and maintaining grassed waterways, many gullies have developed which otherwise would have been prevented. The conversion of many of these gullies to grassed waterways will be necessary.

Waterways must be wide enough to prevent gullying on the sides, and can be used for meadow. These grassed waterways meadows will fit in well with headlands of permanent hay which have been seeded for convenience in turning at the ends of the rows.

Some of the gullies which are to be converted to grassed waterways are of such size that they will have to be filled in and graded before seeding.

In order to furnish a protective cover for the freshly prepared seedbed, and to allow time for settling of the soil, cover crops will be used. Mulching and matting will also assist in the establishment of the seeding.

Diversion of the water from the newly seeded waterway by use of a dike along the side will assist in the establishment in some cases.

Sod Flumes: Sod is usually available on most farms, and gully heads with small drainage areas can often be effectively controlled with sod flumes at low cost.

Fencing Out and Planting to Trees: This economical and practical method for control of some gullies will be used where it is apparent that seeding or sodding will not be practical. In all areas protection from livestock will be necessary.

Permanent Structures: Concrete flumes, drop inlets and earth dams and dikes will be installed as permanent structures.

Diversion Dikes: Diversion dikes will be used to divert water from gully heads, to conduct water into flumes, and to divert water temporarily from waterways or other areas which are being re-vegetated. All outlets will be adequately protected to prevent cutting.

Earth Fills: Gullies with small drainage areas will where possible be controlled by earth dams provided with sod outlets.

Streambank Protection: Streambank protection will consist mainly of piling wing dams. In a few cases channel straightening will be done where oxbows occur.

Contour Furrowing: Contour furrowing will be used to a rather limited extent on old, rundown pastures to prevent gullying while the sod is being renovated and where new permanent pastures are being established.

Contour furrows will be laid out on the exact contour. The distance between furrows will depend on soil type and infiltration capacity. They will be sufficiently close together to provide for the storage of one inch of run-off.

Program For Woodland

Protection of Present Forest Areas: All present forest areas will be protected from grazing if it is practical and feasible to do so. The lack of contiguity in forest areas makes exclusion of livestock on all areas impractical. Continuous timber areas of five, ten, or twenty acres are so interlaced with the pasture areas of approximately the same size that fencing is not always a sound financial investment because of the large perimeter for a corresponding small area. Fencing in the entire area, both woods and pasture, would eliminate some good pasture which for various reasons could not be converted to timber. Under existing conditions both woods and pasture are usually in poor condition, both being well trampled because of lack of forage. With pasture recommendations in effect, both woods and grass areas will benefit. With an increased forage supply the stock will more or less avoid timbered areas except for sufficient shade which can be obtained on the extreme edges.

Although this will result in better forest ground conditions, more infiltration, and consequently, increased tree growth and higher density, no credit will be taken for benefits received.

Present forest areas from which livestock is to be excluded will readily increase in density and growth as the result of better ground surface condition and an increase in sub-soil moisture content. From examination of recently acquired state parks, it is estimated that a

good litter and good tilth of soil can be obtained in five years.

Tree Planting Aside from Gully Control: No large scale planting is to be undertaken although plantings can be very successful if due precaution is exercised. Unfortunately the older plantings, very small areas such as windbreaks, have been located on excellent sites but have not been protected after becoming established. In recent years the State Extension Service and the Soil Conservation Service have been working in this area. Future observations of plantings established by various methods and the species used may result in changes in some recommendations.

Field planting is recommended on areas that are at the present time or will be too badly eroded or gullied (small gullies) to remain in agricultural use. Areas that do not fit well into the farm plan, i.e., odd-shaped or poorly located tracts of land, will also be planted. Walnut, cottonwood, or green ash in a mixture will do well on the better sites, while red elm, green ash, and cottonwood are excellent for the other areas. The average slope of the areas to be planted is 18 percent.

All planting will be done in contour furrows by the modified hole system with a spacing of 6'x6'. Cross sections taken of contour furrows in a plantation established two years ago, a period of time sufficient for good stabilization, gave a storage capacity of 1.32 inches of run-off per unit of area furrowed. Reduction in run-off from the area planted will be effective immediately and is not dependent on closure of canopy and a well defined litter and humus ground cover. Furrows will be made in the fall with planting following in the first and second spring. Latest period of planting is the latter portion of April and the earliest is governed by the character of the weather.

Seedlings or transplants with not less than an 18-inch top will be used for all planting stock. Cottonwood cuttings do not appear to be satisfactory, while spot plantings of walnuts seem quite favorable.

Ground cultivation is not essential but cutting of the larger weeds such as hemp is necessary the first year and under abnormal conditions also the second season.

All plantings will be fenced for protection from livestock.

Planting costs per acre

Stock	1200 trees at $3.18 per M (includes $0.30 transportation)	3.82
Site preparation	Furrowing	1.00
Planting	300 trees per man day, 4 days at $2.00 per day	8.00
Cultivation	1 day at $2.00 per day weed cutting	2.00
Replanting	25% of planting	3.46
Total		$18.28

Management: Timbered tracts, both oak and hardwood types, are even-aged, all-aged, or two-storied. In this region it is well to manage timber areas with such methods that all cutting will be some form of the selection system. In this way crown protection is always present. This will enable some reproduction by seed to supplement the coppice growth.

Field plantings and gully plantings will be carefully managed to avoid a state of over-stocking and a consequent stagnant condition during the early years.

Fire Protection: At present there is no fire problem outside of a few cleanup fires used by farmers to rid themselves of rank brush and weed growth.

Utilization of wood is so close that slash from cutting operations causes no hazard.

Prevention of fire should be a unit in the educational program for those few individuals who practice annual burning.

Table C-5 – Total forest area for present and recommended land use by major physical delineations (percent).

Major physical delineation	Present land use: Unprotected	Recommended land use: Unprotected	Protected	Gully	Total
9-B-1	.25%	--%	.25%	.02%	.27%
9-B-2	.42	---	.55	.03	.58
9-C-2 & 3	---	---	.22	1.08	1.30
11-C-2	1.34	---	1.13	1.17	2.30
11-C-3	.63	---	1.00	1.58	2.58
11-D-1	37.69	10.53	27.25	.28	38.06
11-D-2	8.11	.57	9.36	.72	10.65
11-D-3	5.47	1.44	5.71	1.06	8.21
150-C&D-1 & 2	6.30	1.85	6.20	.81	8.86
Average	1.92	.37	2.02	.51	2.90

Table C-6 – Rods of fence, area to be planted, and cost of each for establishing recommended forest practices (per square mile by major physical delineations).

Major physical delineation	Fence to be constructed: Present forest area: rods	Present forest area: cost	Field planting: rods	Field planting: cost	Gully planting: rods	Gully planting: cost *	Area to be planted: Field planting: acres	Field planting: cost	Gully planting: acres	Gully planting: cost
9-B-1	13	$ 6.50		$		$		$	.1	$ 1.83
9-B-2	6	3.00			2	2.16	.8	14.62	.2	3.66
9-C-2 & 3					156	168.79	1.4	25.59	6.9	126.27
11-C-2	19	9.50	6	3.00	259	280.24	1.2	21.94	7.5	137.25
11-C-3	6	3.00	12	6.00	335	362.47	2.4	43.87	10.1	184.23
11-D-1	325	162.50	5	2.50	86	93.05	2.0	36.56	1.8	32.94
11-D-2	198	99.00	66	33.00	111	120.10	11.8	215.70	5.3	96.99
11-D-3	89	44.50	77	38.50	236	255.35	12.2	223.02	6.8	124.44
150-C&D-1&2	33	16.50			195	210.99	11.4	208.39	5.2	95.16

* This cost is present worth of one original fence construction and three replacements in 45 years.

SECTION II - MAJOR GULLY CONTROL

Number of Structures: In the survey a major gully was defined as a gully whose cross-sectional area was 646 square feet or greater or the lateral gullies contiguous to trenches of this size. The control of these gullies are beyond the farmers' scope and financial status. The gullies are vertical sided trench-type ranging in depth from 20 to 45 feet. Several overfalls within a single gully as well as numerous lateral gullies is a common occurrence.

The gullies occur in the area between the city of Cherokee, Iowa, and the Missouri River flood plain. This area was divided into three gully zones according to topography and extent of gully erosion (Figure C-1).

The lower gully zone, next to the Missouri River alluvial plain, contains approximately 368 square miles. This zone is predominantly D slope and the major soils are Knox silt loam and Brown Phase Marshall silt loam. The gully erosion in this zone is very serious.

The intermediate zone occupies about 458 square miles. C slopes are predominant in this area and the predominant soils are Marshall silt loam and Brown Phase Marshall silt loam, with some Knox silt loam. The gully erosion in this zone is serious.

The upper zone has an area of approximately 1168 square miles. The gully erosion in this zone is moderate. The predominant soils are Marshall silt loam, and Brown Phase Marshall silt loam. Most of the zone is made up of B slopes, with some C slopes present.

Drainage areas were selected at random in each zone. The drainage areas were selected regardless of size or other features in order to obtain a true sample of the gully problem in each zone.

Thirteen drainage areas totalling 41.25 square miles were selected in the lower zone. This was a 11.2% sample of the zone containing the most serious gully erosion. Eight drainage areas comprising 22.05 square miles or 4.8 percent of the zone were selected in the intermediate zone. Eight samples containing 22.43 square miles or 1.92 percent of the zone were selected in the upper zone, where the gully erosion is moderate.

Survey Procedure: Each sample drainage area was inspected in the field, and sufficient field data were obtained to determine the type and location of structures required to completely control the gully and to estimate the cost of the control. It was assumed that all structures in the main stems of the gullies would be drop inlet or similar earth fill soil saving dams of standard design. Estimates based on preliminary designs developed the yardage of fill, the quantity of reinforced concrete and appurtenances required to control each gully in the sample watersheds.

LITTLE SIOUX WATERSHED

MINNESOTA & IOWA

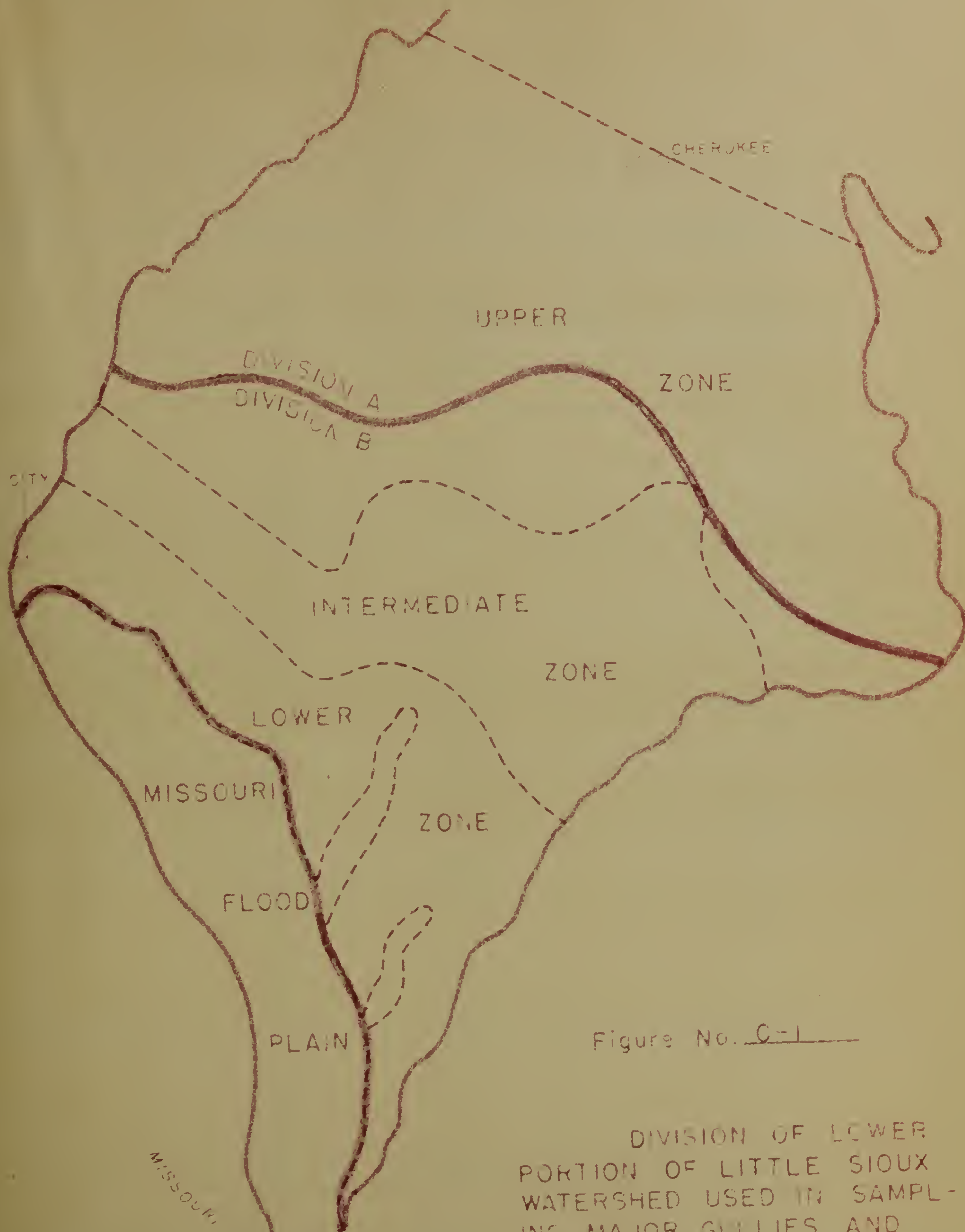


Figure No. C-1

DIVISION OF LOWER PORTION OF LITTLE SIOUX WATERSHED USED IN SAMPLING MAJOR GULLIES AND HIGHWAYS

Table C-7 Major Gully Control

Estimates of Quantities of materials on main stem structures - 368 square miles.

Lower Zone

Drainage area no.	Dam No.	C. Y. Concrete	C. Y. Fill	Acres in Drainage Area
1	1	110	9090	1640
		110	9090	1640
4	1	195	12500	3274
	2	340	18130	
		535	30630	3274
5	1	7	1500	791
	2	110	12500	
	3	192	16425	
		309	30425	791
6	1	130	11500	2535
	2	95	12500	
	3	160	11800	
	4	9	1500	
		394	37300	2535
9	2	715	18700	7463
	3	220	9000	
	4	155	15300	
		1090	43000	7463
10	1	110	12500	700
	2	130	8000	
		240	20500	700
11	1	408	9720	5400
	2	417	13470	
	3	215	17550	
		1040	40740	5400
13	1	50	7830	2370
	2	150	12420	
	3	110	17500	
	4	90	9090	
	5	100	16400	
		500	63240	2370
Total	23	4218	274925	24173

Total area sampled 41.25 square miles

Drainage areas No. 2, 3, 7, 8 and 12 required no control.

Table C-7 (Continued)

Drainage area no.	Dam No.	C. Y. Concrete	C. Y. Fill	Acres in Areas
17	1	295	23100	1900
	2	260	13500	
	3	185	12500	
		740	49100	1900
19	1	280	27600	2225
	2	125	22200	
	3	120	18800	
		525	68600	2225
32	1	95	9000	1400
	2	5	1000	
		100	11000	1400
Total	8	1365	128700	1400

Total area sampled 22.05 square miles.

Drainage areas 14, 15, 16, 18, 20, 21, 31, and 34 required no control.

Table C-8 – Number of major gully control structures required, main stems of gullies.

By zones

Zone	No. of dams in sample	Sq. mile in sample	Dams per sq. mile	Sq. mile in zone	Dams needed in zone
Lower	23	41.25	.557	368	205
Intermediate	8	22.05	.368	458	166
Upper	0	22.43	0	1168	0
Total					371

By Counties

County	Sq. mile lower zone	Sq. mile intermed-iate zone	Dams needed lower zone	Dams needed intermed-iate zone	No. with highway benefits	No. without highway benefits
Ida	0	150	0	54	27	27
Monona	161	5	90	2	46	46
Woodbury	207	303	115	110	112	113
Total	368	458	205	166	185	186

By watersheds

Watershed	Sq. mile lower zone	Sq. mile intermed-iate zone	No. of dams lower zone	No. of dams in-termediate zone	Total no. of dams
Little Sioux	72	112	40	40	80
Maple	100	184	56	67	123
West Fork	196	162	109	59	168
Total	368	458	205	166	371

The data pertaining to the samples representative of each zone were expanded to the zone by the ratios of the area of the sample to the area of the zone represented.

The data show that a total of 371 structures are needed to control the main stem development of the gullies. All of these structures are needed in the lower and intermediate zones, with 50% of them located on roads where the fill will be used for a roadway and will replace bridges now expensive to maintain.

In addition to these structures a total of 447 concrete flumes and 73 earth fill, drop inlet type, dams of a smaller size than those required in the main stem of the gullies will be required to stabilize the grades of other gullies and prevent further head cutting. These structures will be located on individual farms and their number, size, and type were determined in connection with the farm land treatment program of which they are part. Their installation is necessary to the successful control of the so-called major gully systems.

SECTION III - COST ESTIMATES

Costs of Farmland Treatment

Unit Costs: Unit costs for installing the farm land treatment program are given in Table C-9. Cost information was obtained from Soil Conservation Service camps located in or near the Little Sioux watershed as well as from other local sources. An effort was made to have these costs conform as nearly as possible to what they would actually be using local labor on force account, equipment and materials. The seed, lime and fertilizer costs were determined locally.

Installation Costs: The costs of installing the supplementary measures were determined by applying the unit costs, to the amounts of each practice, and are shown in Table 5 of the Report for 100% cooperation. The total cost of installation is shown in Table 6 of the Report.

Maintenance Costs: The costs of maintaining the program on farms consists of the additional costs of operation after the program is installed over the costs that would occur if the program was not installed. These costs were determined by subtracting the operating expenses in the future without a program from the operating expenses with a program. These additional expenses were determined by budget analyses for the sample farms (see Appendix E for discussion of study of sample farms). Average maintenance costs were derived for each physical delineation and applied to the areas of the delineations composing the Divisions to obtain an estimate of total maintenance cost. The maintenance costs by delineations are given on Table C-10 and the cost by Divisions in Tables 6 and 9 of the Report.

Table C-9 - Unit costs for installation of the remedial program

Item	Unit	Unit Cost: Labor	Unit Cost: Equipment & material	Unit Cost: Total
Terracing	acre	$ 2.50	$ 3.50	$ 6.00
Diversion dikes	foot	.02	.03	.05
Fence construction	rod	.10	.40	.50
Gully control -----	acre	3.00	5.00	8.00
Gully control xxxxx	acre	5.00	20.00	25.00
Gully control 11111	acre	20.00	80.00	100.00
Concrete flume	cu. yd.	12.00	8.00	20.00
Concrete flume	each	354.00	236.00	590.00
Drop inlet	each	1162.00	1210.00	2372.00
Sod flume	sq. yd.	.39	.01	.40
Sod flume	each	87.30	2.70	90.00
Earth dike	each	4.83	2.17	7.00
Channel straightening	foot	.06	.18	.24
Streambank protection	foot	.64	.36	1.00
Contour furrowing	acre	2.00		2.00
Tree planting	acre	13.50	4.78	18.28
Sweet clover seed	pound			.08
Alfalfa seed	pound			.26
Red clover seed	pound			.24
Alsike clover seed	pound			.22
Brome grass seed	pound			.10
Timothy seed	pound			.07
Lime	ton			2.00
Phosphate	ton			25.00
Cost of planning				
Division A	acre			1.38
Division B	acre			1.93

Table C-10 - Maintenance Costs of Farmland Treatment Program Assuming All Farmers Participating in Program.

Delineation	Number of Farms	Maintenance Cost per Farm	Total Maintenance Cost
9B-1	1,542	256	$ 394,752
9B-2	2,051	202	414,302
9C-2&3	653	315	205,695
11C-2	267	135	36,045
11C-3	647	282	182,454
11D-1	47	-10	-470
11D-2	442	126	55,692
11D-3	523	346	180,958
150C&D-2&3	586	171	100,206
	6,758		1,569,634

Cost of Major Gully Control Program

The cost of installing the major gully control program is estimated on Table C-11.

A local agency (or agencies) is expected to contribute to this program by placing, or defraying the cost of placing, one-half of the fill in the earth dams (see ii, Summary Report). It is probable that the County highway departments can arrange to assume this responsibility by placing the fill for those dams that will be used in place of bridges. It will be seen from Table C-11 that the cost of placing one-half of the earth fill will be approximately $368,410.

The responsibility of inspecting, repairing and replacing the major gully works is to be assumed by a local agency, or agencies. The estimated costs of maintaining these works is derived in Table C-12.

Table C-11 Costs of major gully control program

Zone	No. Dams in Sample Main Stem	Earth Fill Cu. Yds.	Concrete Cu. Yds.	Earth Fill at $0.125	Concrete at $20	Total Cost Sample	Ratio Sample to Zone	Total Cost Zone
								Dollars
Lower	23	274,925	4,218	34,365	84,360	118,725	8.921	1,059,146
Intermediate	8	128,700	1,365	16,087	27,300	43,387	20.771	901,191
Total								1,960,337
Plus 15% for contingencies, etc.								294,051
								2,254,388

Other Structures

Concrete Flumes	447 at $590 ea.	$281,430	
Earth Dams	73 at 2,372 ea.	173,156	
	Total	454,586	
	Plus 15% for contingencies, etc.	68,188	522,774

Total 2,777,162

Cost of earth fills:	Lower 34,365 x 8.921 =	306,571
	Upper 16,087 x20.771 =	334,143
		640,714
	Plus 15% for contingencies, etc.	96,107
		736,821

Table C-12

CALCULATION OF MAINTENANCE COSTS

MAJOR GULLY CONTROL WORKS

Inspection			
1 Engineer	1/2 year @ $2,000	1,000	
Transportation	10,000 miles @ .04	400	
Office rent and services		1,200	
			2,600
Repair			
1 Engineer	1/4 year @ $2,000	500	
Labor	4 man years @ $800	3,200	
Materials		2,000	
Transportation	- Truck: 5000 miles @ .06	300	
"	- Other: 5000 " @ .04	200	
			6,200
Replacement			
Replacement of one main structure every other year 1/2 @ $6000		3,000	
Replacement of concrete flumes each year 5 @ $600		3,000	
Replacement of one earth dam on lateral each year 1 @ $2,400		2,400	
1 Engineer	1/4 year @ $2,000	500	
Transportation	2000 miles @ .04	800	
			9,700
Contingencies			1,500
	Total		20,000

APPENDIX D

PHYSICAL EFFECTS OF THE REMEDIAL PROGRAM

CONTENTS

SECTION I - EFFECT OF THE REMEDIAL PROGRAM ON FLOOD RUN-OFF

Hydrologic Characteristics of the Little Sioux Watershed

A brief description of the Little Sioux Watershed is given in the main Report. More detailed information on soils, vegetal cover, land use and farming practices are given in Appendices A and B. The descriptive matter in this Appendix will, therefore, be limited to brief discussion of storm rainfall, flood runoff, and channel characteristics.

Storm Rainfall: High intensity storms of short duration which center over the small tributaries of the Little Sioux, or several high intensity storms of short duration affecting different portions of the Little Sioux proper are the conditions which create the majority of floods. Snow-melt or a combination of rainfall and snow-melt produce floods of considerable size. However, as this condition occurs during the early spring, it results in relatively small agricultural damage.

Storms of high intensities and short duration are common and often follow in rapid succession. Many of the floods which have occurred were caused by several of these storms affecting different parts of the watershed and producing the effect of a more general storm. Records indicate that storms of this nature occur on the average at least once during each of the months of June, July and August.

Flood Run-off: There is considerable variation in the types of floods that occur on the different watersheds. Elliott Creek, for example, is a small watershed with a relatively steep channel gradient. Floods in this watershed occur frequently, but the period of inundation is short. The Little Sioux proper, being a much larger watershed and having a rather flat channel gradient, does not reach flood stages as frequently, but when it does the period of inundation is usually much longer. The floods on the smaller watersheds, however, transport more silt per volume and in this way cause much damage to crops and drainage ditches by deposition.

During the relatively short period of record, the watershed has never experienced exceptionally high discharges per unit of watershed area. The maximum recorded discharge at Correctionville occurred on June 12, 1919, when 4.37 csm was produced from 2450 square miles and at Spencer, an area of 1030 square miles produced 3.55 csm in the spring of 1936.

Channel Characteristics: There is considerable variation in stream channel gradient among the tributary watersheds studied. The Little Sioux proper has an average fall of approximately 1.7 feet per mile, through the flood damage area. Gradients through the flood damage area on the smaller tributaries are approximately as follows: Maple River 5.5 feet per mile, West Fork 6.3 feet per mile, Elliott Creek 8.3 feet per mile. Where these streams enter the Missouri River Flood Plain, there is an abrupt change in channel gradient. From this point to their confluence with the Missouri River, the gradient is approximately 1 foot per mile. This abrupt change in gradient is conducive to sediment deposition. These sections of channel have been maintained for a number of years by drainage districts.

Levees have been built on many of the channels during the process of removing sediment. Sediment deposits have reduced channel capacities to a point where frequent over-topping of the levees is experienced.

Records Used in Hydrologic Calculations

Rainfall: The locations of rain gages in or near the Little Sioux watershed are shown by Figure D-1. The Sioux City gage is of the automatic-recording type and rainfall intensity has been recorded at this gage ever since 1907. The storms of flood producing potentialities recorded at this station were, as will be shown later, used in calculating floods and evaluating the physical effects of proposed programs.

Run-off: Figure D-1 shows the location of stream gages in the watershed. Records have been maintained at Correctionville from 1918 to 1925, 1929 to 1932 and from 1936 to the present time. Records are available at Spencer since 1936. The Maple River at Turin and the West Fork at Holly Springs have been gaged only since 1939.

Procedure for Calculating Flood Run-off

The quantity of rainfall and run-off data available for use in the evaluation of possible flood control programs for the Little Sioux watershed was, as is evident from the foregoing, meager. The only available record of the intensity of rainfall was for Sioux City just outside of the southwestern boundary of the watershed. The only substantial record of streamflow was at Correctionville, on the main stream of the Little Sioux and having a contributing area of 2450 square miles. It was, therefore, necessary to utilize these records to the fullest extent and to synthesize floods and rainfall for the major portion of the watershed from the records available.

The major phases of the procedure used in evaluating the farmland treatment program are briefly described in the following:

1. It was assumed that the 16-year record of run-off at Correctionville was reasonably representative of the average flood characteristics of the watershed above Correctionville, and that the benefit calculated from the reduction of each flood in this record, divided by the number of years in the record, would be a measure of the average annual flood benefit that would accrue from the installation of the farmland treatment program on the watershed of the Little Sioux above Correctionville.

2. It was assumed that this flood record would represent the characteristics of the Maple River if the volumes of run-off of the floods contained therein were modified by the difference between the average rainfall versus run-off relationships for the two watersheds. The average rainfall versus run-off relationship for the Maple was obtained from the records on the Maple at Turin from 1939 to date.

FIGURE D-1

LITTLE SIOUX WATERSHED
MINNESOTA-IOWA

LOCATION OF PRECIPITATION
AND
STREAM-FLOW GAGES

3. It was assumed that the storms of flood producing potential recorded at Sioux City during the period of record of the gage at that location could, during the course of time, be experienced at a gage centrally located on the Elliott Creek or West Fork watersheds. The storms occurring during the period from 1912 through 1927, inclusive, were adopted as an "evaluation storm series" for these tributaries.

4. From a study of the rainfall characteristics of storms recorded at Sioux City and the average rainfall-run-off relationships for the watershed above Correctionville average intensity and depth of rainfall relationships were developed and average storms that would produce floods of a range of magnitude on the Little Sioux and Maple rivers were constructed.

5. By use of the infiltration theory of run-off the average reduction in floods that had occurred on the Little Sioux and could occur on the Maple were calculated by determining the difference in surface run-off that would be produced by the average storms with the watersheds in their present and planned condition.

6. By use of the same theory the floods that would occur on the Elliott and West Fork Creeks, if they were subjected to the storms recorded at Sioux City, were calculated for both present condition of these watersheds and for their conditions under the farmland treatment program.

7. The areas inundated by each flood in the two series under present and future land conditions were determined and with this information it was possible to estimate what the flood damages would be for the Little Sioux and Maple over a 15-year period and for Elliott and West Fork tributaries over a 16-year period.

Each of these major divisions of the procedure are briefly described in the following. Supplement A describes the procedures used in deriving and applying infiltration data.

<u>The Evaluation Flood Series for the Little Sioux and Maple Rivers</u>: Each flood in the 15-year record at Correctionville was used in an evaluation series to determine the physical effect of the remedial program on floods that cause damage on the Little Sioux and the Maple Rivers. The hydrographs at Correctionville were analyzed to determine the volume of runoff caused by certain storms. This volume was taken as the total runoff in the flood hydrograph minus normal depletion indicated by the streamflow preceding the flood rise. The rainfall that produced the runoff was determined, for each event, for the area above Correctionville by Horton-Thiessen weighting of rainfall recorded by standard rain gages in operation at the time of the flood. The areal average rainfall was plotted against the flood runoff and a curve fitted to the plotted (Figure D-2) points to determine the average rainfall-runoff relationship. Similar relationships were also determined for the Maple River at Turin from the available record at Turin. The relationship between volumes of runoff

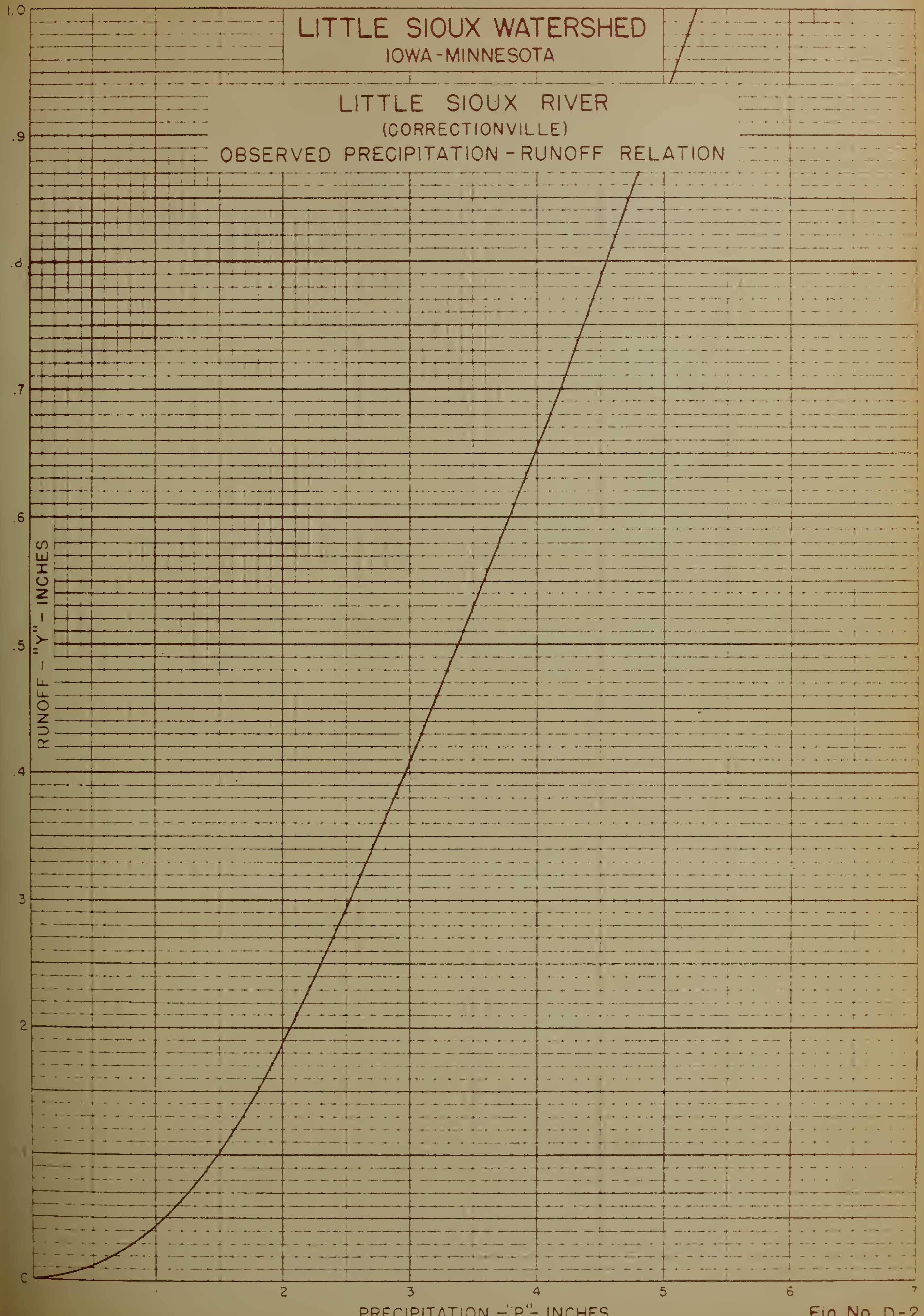

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
LITTLE SIOUX RIVER
(CORRECTIONVILLE)
OBSERVED PRECIPITATION-RUNOFF RELATION
RUNOFF - "Y" - INCHES
PRECIPITATION - "P" - INCHES
1.0
.9
.8
.7
.6
.5
.4
3
2
C
2
3
4
5
6
7

Fig. No. D-2

for identical depths of rainfall on the watersheds of the Little Sioux and the Maple were used to convert the evaluation flood series for the Little Sioux to a flood series of equal length for the Maple River.

The Evaluation Storm Series:

Derivation for Elliott Creek and West Fork: To derive a series of storms to be applied to each of these watersheds a study was made of the recording rain gage record at Sioux City. The record was examined to find a period containing a suitable evaluation series. The period from 1912 through 1927, inclusive, appeared to be reasonably normal and was adopted. For the purpose of evaluation it was decided to subject each watershed to the storms recorded at Sioux City during this period. For all of the significant storms during the period the intensities of rainfall were calculated by five-minute periods. The rain periods in these storms were then analyzed to determine the amounts of rainfall occurring over and above given intensity levels; a quantity sometimes called the "excess rainfall" and often designated by the symbol P_e. The values of P_e were then plotted against intensity to form excess rainfall curves. On the same diagram the durations of rainfall at the given intensity levels were also plotted to form "duration of excess" curves. This latter variable is hereinafter represented by the symbol T_e. The way in which the P_e and T_e curves were used will be explained subsequently.

It should be clearly understood that the storms were taken as they were actually recorded at Sioux City; that is, the depth of rainfall, the number and sequence of storms, and the rainfall intensities used in establishing the evaluation storm series for Elliott Creek and the West Fork were identical with those recorded at the Sioux City gage. Since the centers of the storms with respect to the Sioux City gage could occupy the same relative positions with respect to the center of the tributary watersheds to which they were transposed, and since the area of the tributaries were small, the catch at the gage could, without danger of great error, be taken as the average rainfall on the tributary. The calculated run-off from these storms was used as a series of evaluation floods on Elliott Creek and the West Fork.

Index of Antecedent Rain: At the time the storm analysis was made an index of antecedent rain was also calculated. To obtain this index the daily rainfalls for 10 days preceding the day on which the flood producing storm occurred were divided by the number of days each quantity preceded the storm and the quotients so obtained were added. Expressed in symbols this index is:

$$\Sigma \frac{P}{T} = \frac{P_1}{1} + \frac{P_2}{2} + \cdot \cdot \cdot \cdot \cdot \cdot + \frac{P10}{10}$$

in which P_1, P_2, ...etc., are the rainfall, 1, 2 ....etc., days before the storm. In the interest of brevity the above quantity is designated hereinafter by the letter Σ.

Derivation for the Little Sioux and Maple Rivers: Six average storms were developed for the Little Sioux and Maple Rivers. To do this, six values of peak discharges were selected from the Correctionville flood record which would cover the range of experienced floods. With a peak discharge for the selected value the volume of run-off was determined from the peak discharge-volume relation. With the volume of run-off known the causitive precipitation was determined from the rainfall-run-off relation. During the course of the study of the rainfall record at Sioux City it was determined that the average maximum intensity of flood producing rainfall was 2.50 inches per hour and that an average pattern of rainfall intensity distribution could be obtained. Using the value of 2.50 inches per hour for maximum intensity and the average distribution obtained from the Sioux City record, average P_e and T_e curves were developed for the six magnitudes of rain storms that would produce the six discharges selected to represent the range of possible events on the Little Sioux and the Maple Rivers. The manner in which these average storm patterns were derived is illustrated by Table D-1 and an example of the P_e and T_e curves plotted appears on Figure D-3.

Infiltration Data: There exist on the Little Sioux watershed many complexes (of soil, cover, condition, and treatment) that differ with respect to their infiltration characteristics. It was necessary to secure data applicable to these complexes. The data were determined by use of "infiltrometers". These are instruments for applying artificial rainfall to small plots and from the results of such application it is possible to determine the level of rainfall intensity over and above which the depth of rainfall (the excess rainfall) equals the measured run-off. For purposes of this report this value, or index, is denoted by the letter Ø. The rate of application of rainfall by an infiltrometer is known during any given test and the rate of run-off is measured continuously. This makes it possible to determine, for any instant, the difference between the two rates or the "rainfall minus run-off" rate. This is the rate at which water is entering the soil and being stored on the surface of the plot. The values of the rainfall minus run-off rate were plotted against the time of excess T_e. By the methods described in Supplement A the curves thus formed were converted to Ø curves.

For each of the complexes investigated measurements were made on several plots and on each plot two "runs" were made, - the first being designated as the "initial run" and the last, which was made 24 hours later, being called the "wet run". The rainfall minus run-off curves for all wet runs on a given complex were composited and the Ø curves developed from this composite curve.

By the methods described in Supplement A, Ø curves for wet conditions were derived for all the complexes on which measurements were made. By the system of interpolation explained in the Supplement similar curves were also constructed for the covers and treatments on which no measurements were made. The end product was a series of Ø curves for each of the following factors in combination with each of the six different significant soil groups:

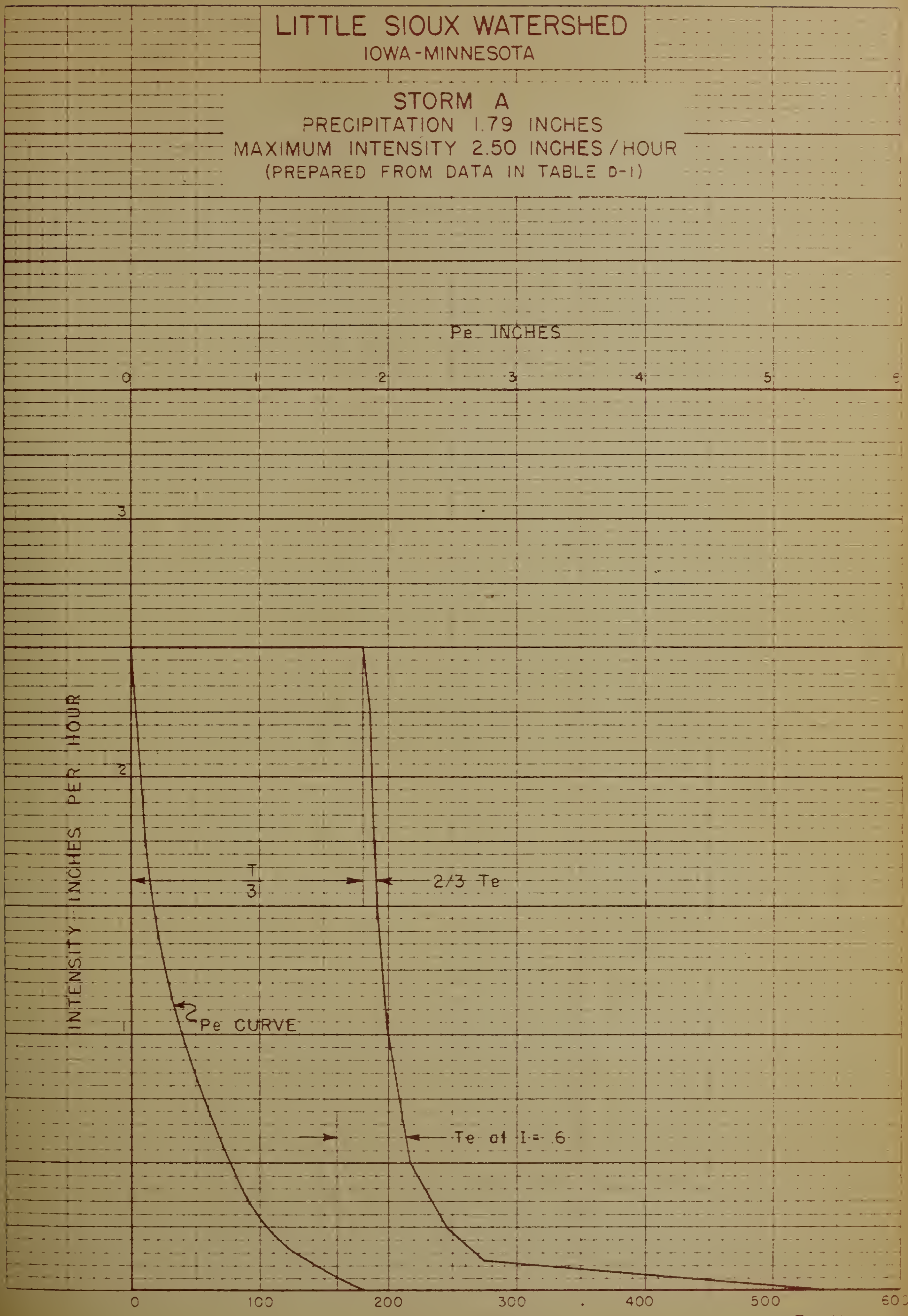

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
STORM A
PRECIPITATION 1.79 INCHES
MAXIMUM INTENSITY 2.50 INCHES / HOUR
(PREPARED FROM DATA IN TABLE D-1)
Pe INCHES
0
1
2
3
4
5
3
2
1
INTENSITY INCHES PER HOUR
T/3
2/3 Te
Pe CURVE
Te at I = .6
0
100
200
300
400
500
600
TIME — MINUTES

Fig. No. D-3

TABLE D-1. DEVELOPMENT OF AVERAGE STORM PATTERN

Storm A - precipitation = 1.79 inches   maximum intensity = 2.50 inches per hour

1	2	3	4	5	6	7	8	9	10
$\frac{I}{Imax}$	$\frac{Pe}{P}$	"N"	I	Pe	Te	2/3 Te	$\frac{T}{3}$	$\frac{T}{3}$ + 2/3 Te Hours	$\frac{T}{3}$ + 2/3 Te Minutes
1.0	.0	.0	2.50	.0000	.000	.000	2.98	2.98	179
.9	.017	.19	2.25	.0304	.136	.091	2.98	3.07	184
.8	.038	.24	2.00	.0680	.172	.115	2.98	3.10	186
.7	.066	.33	1.75	.1180	.236	.157	2.98	3.14	188
.6	.103	.44	1.50	.1843	.315	.210	2.98	3.19	191
.5	.153	.56	1.25	.2740	.401	.267	2.98	3.25	195
.4	.217	.73	1.00	.3885	.522	.348	2.98	3.33	200
.3	.300	1.03	0.75	.5370	.738	.492	2.98	3.47	208
.2	.422	1.35	0.50	.7550	.967	.643	2.98	3.62	217
.1	.610	2.31	0.25	1.0300	1.653	1.100	2.98	4.08	245
.05	.757	3.30	0.125	1.3550	2.360	1.570	2.98	4.55	273
.00	1.000	12.50	0.000	1.7900	8.950	5.970	2.98	8.95	537

Column 1 convenient values ranging from 0 to 1.0
2 from Figure D-5
3 from Figure D-5
4 Imax x column 1
5 precipitation x column 2
6 (precipitation ÷ Imax) x column 5
7 2/3 column 6
8 T = Te when $\frac{I}{Imax} = 0 \therefore \frac{8.950}{3} = \frac{T}{3}$
9 column 7 + column 8
10 column 9 x 60

Season: Winter
Summer
Fall

Covers: Row crops unimproved
Row crops improved
Legume
Small grain
Grass legume
Pasture unimproved
Pasture improved

These curves were made available for all significant complexes on the watershed in its present and future condition.

Effect of Antecedent Rain: All of the foregoing deals only with the Ø curves for wet conditions. To derive Ø curves for soils with different degrees of wetness it was assumed that the average Ø curve determined for a given complex from the "initial runs" would represent a wetness index of $\Sigma = 0.1$ and that the average curve from the wet runs would represent an index of $\Sigma = 0.7$. Curves of $\Sigma = 0.2$ and 0.5 were interpolated to cover the range of Σ values which were evident in the storms used in the evaluation series.

Effect of Season: Seasonal influence was evaluated by a study of data obtained on the same complexes during the different seasons of the year as described in Supplement A.

The Final Ø Curves: The Ø curves for each cover on each soil were drawn on transparent material to the same scale as the P_c and T_c curves for the evaluation storms so that they could be used as templates in the process of estimating run-off. Figure D-4 illustrates the final Ø curves and the manner in which they were used.

It will be noted that a vertical shifting of the curves make them applicable to the different seasons. In this way the construction of separate templates for different seasons was avoided. The manner in which the Ø curves were used in estimating run-off follows.

Calculation of Run-off:

Run-off for Individual Complexes: The run-off for each storm in the evaluation series for Elliott Creek and the West Fork taken from the Sioux City record and for each of the six average storms developed for the Little Sioux and Maple Rivers was estimated for each of the important complexes present in the watershed. The procedure used is illustrated in Figure D-4. The transparent Ø templates were laid over the T_e curve and the point of intersection established. The value of Ø at this intersection is, by definition, the intensity above which the excess rainfall equals the surface run-off. To estimate the run-off, therefore, it was only necessary to enter the P_e curve with the given value of Ø in the manner illustrated by Figure D-4.

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA

Φ CURVES
MARSHALL SILT LOAM
CORN

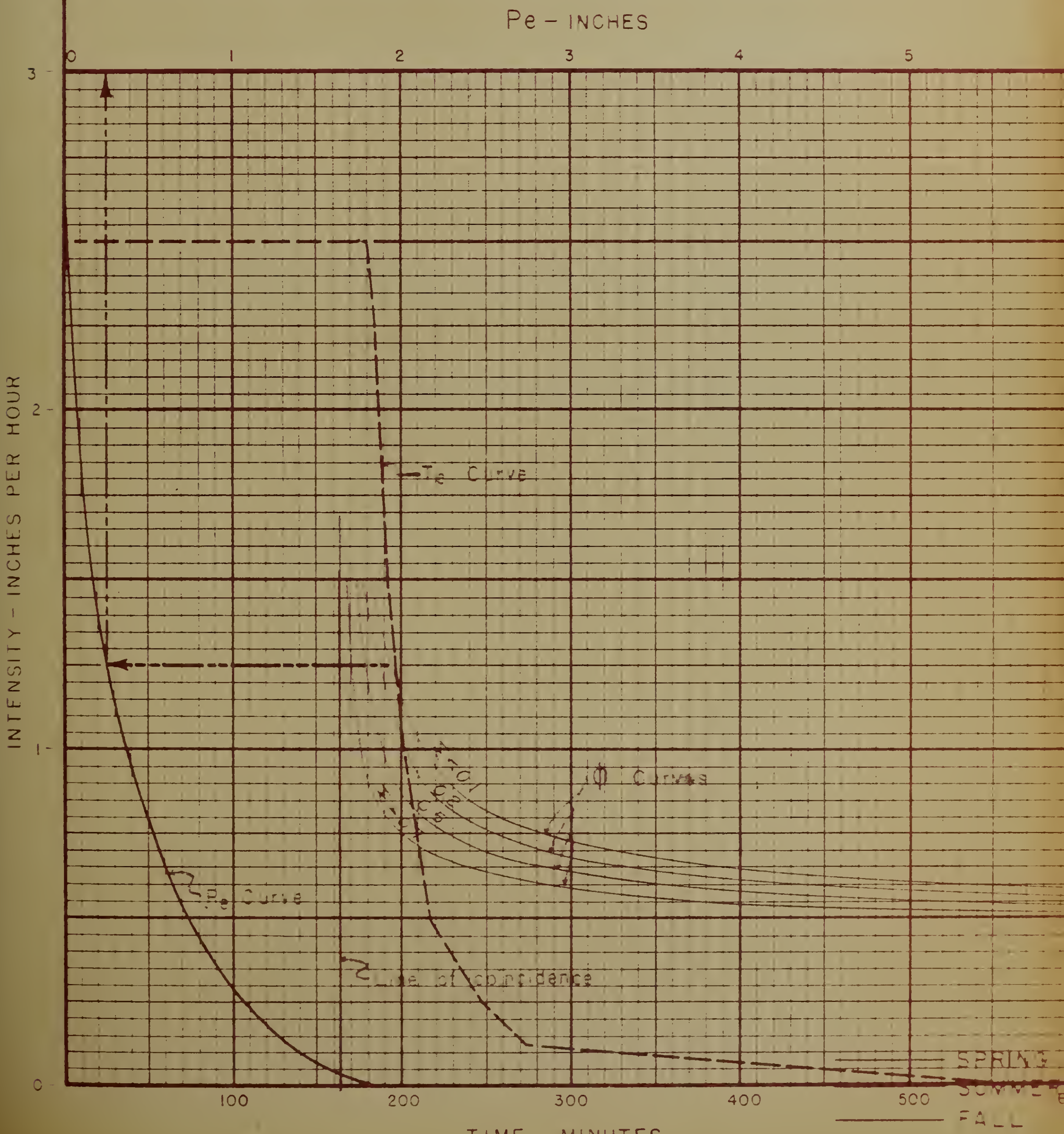


Fig. No. 5-4

TABLE D-2. DETERMINATION OF RUN-OFF ON THE MAPLE RIVER WATERSHED FOR STORM A

(1.79 inches rainfall)

Delineation	Sq. Mile in Watershed	Average Pe	Sq. Miles Inches
26a	138.1	.120	16.57
9-B-1	110.1	.234	25.76
9-B-2	231.7	.213	49.35
9-C-2 & 3	92.1	.235	21.64
11-C-2	23.8	.273	6.50
11-C-3	60.0	.268	16.08
11-D-1	7.6	.152	1.16
11-D-2	21.3	.203	4.32
11-D-3	47.8	.234	11.19
150-C & D - 1 and 2	7.5	.159	1.19
Total	740.0		153.76
Run-off in inches			.208

Run-off for the Watersheds: Having the estimated run-off for each storm by complexes the run-off for any watershed was determined by multiplying each complex run-off by the area of the complex to determine the volume of water yielded. These volumes were then added and the total divided by the drainage area to obtain the depth of run-off from the watershed. Table D-2 is a sample of the calculations made for the Maple River.

Adjustment for Contour Tillage and Furrows: Estimates were made of the additional surface storage provided by contour tillage. These estimates were based on field measurement and available experimental data and amount to 0.09 inches average storage during the growing season. The type of contour furrow designed for installation under the program will provide storage equal to one inch of rainfall.

In calculating run-off from an area to be contour tilled or furrowed these estimates of reduction in run-off were used if the calculated surface run-off without contour tillage or furrows equalled or exceeded the additional storage provided by these measures. Where the surface run-off did not equal the additional storage capacity the value of the run-off from the area to be contour tilled or furrowed was deducted from the total run-off for the watershed. These deductions were made for storms which would occur during the season of effectiveness of the measures.

Flood Series and Their Use: The calculations outlined above were made in connection with all storms from the Sioux City record selected to provide a flood evaluation series for Elliott Creek and the West Fork. The calculations resulted in a series of floods that would occur on these streams without and with the farmland treatment program in effect over a 16-year period of normal storm experience.

The same calculations were made for the six average storms that would produce floods of different magnitudes on the Little Sioux and Maple Rivers. The relationship established for the present and future run-off from the six storms, used in the evaluation of the remedial program on these watersheds, was entered with the flood volumes in the flood evaluation series derived from the Correctionville record to determine the future volumes of each flood in the series with the program in operation on the Little Sioux and Maple River watersheds. Tables D-3 and D-4 show the discharge in flood series with the watersheds in their present and in their planned condition. Figures 2 to 5, inclusive in the Report, show the percent reduction in flood volume expressed in terms of the present volumes.

Check on Calculated Floods: The calculated volumes of run-off for all storms with the watersheds in their present condition were plotted against depth of precipitation and the average curves fitted to the plotted points was compared with the average precipitation-run-off observed at the existing stream gages. The check indicated that the calculated values of storm run-off compared reasonably well with the observed data. Figure D-4 shows the comparison for the Maple River.

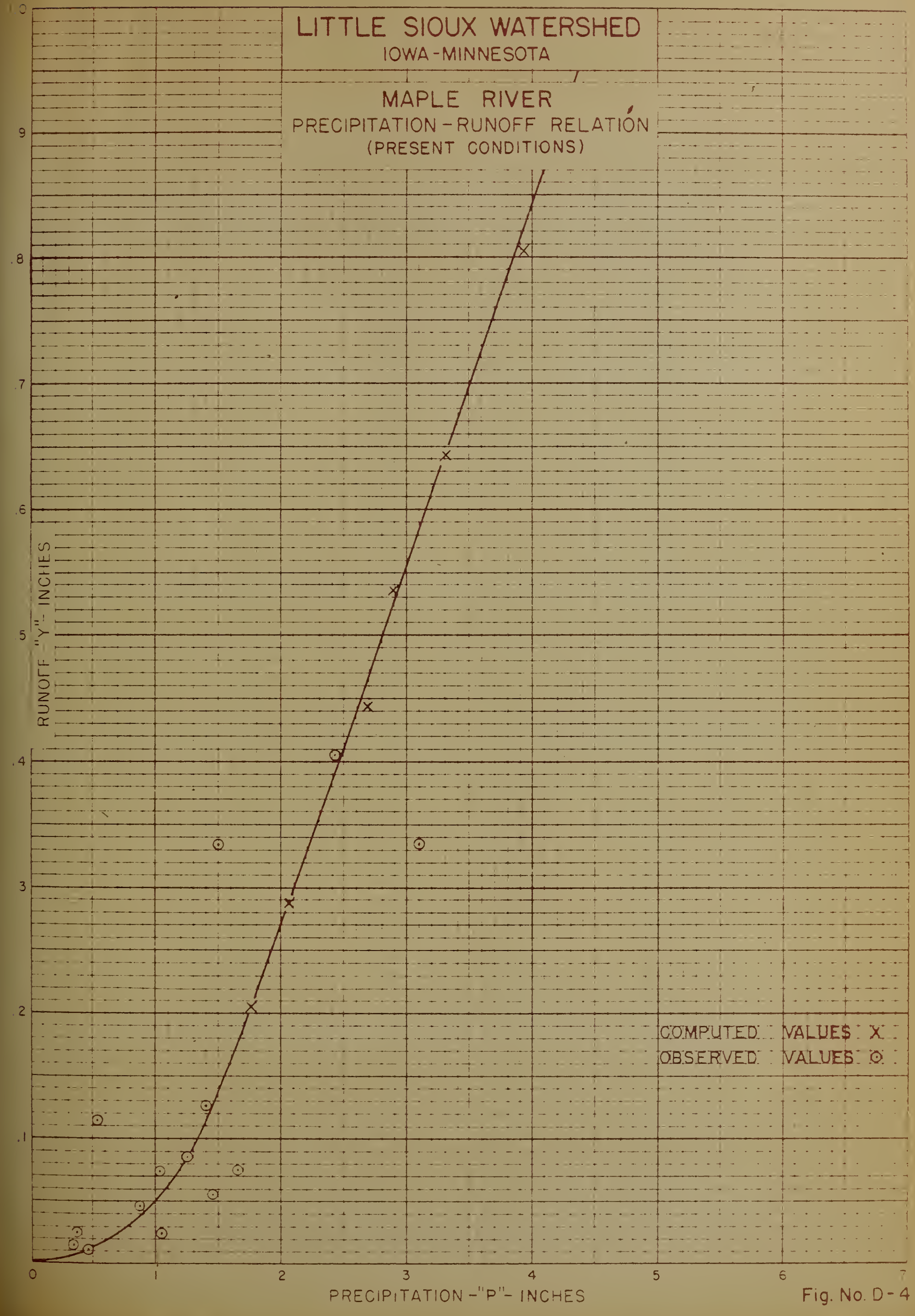

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
MAPLE RIVER
PRECIPITATION - RUNOFF RELATION
(PRESENT CONDITIONS)
RUNOFF "Y" - INCHES
PRECIPITATION -"P"- INCHES
COMPUTED VALUES X
OBSERVED VALUES ⊙
Fig. No. D-4

TABLE D-3. CALCULATED VOLUMES OF RUN-OFF FOR STORMS USED IN EVALUATION SERIES. WATERSHEDS IN EXISTING CONDITION AND WITH THE FARM LAND TREATMENT PROGRAM IN EFFECT.

Date of Storm	Run-off Volume in Inches, Conditions: Existing (Little Sioux Watershed)	Future (Little Sioux Watershed)	Date of Storm	Run-off Volume in Inches, Conditions: Existing (West Fork Watershed)	Future (West Fork Watershed)
6-3-18	.32	.28	5-26-12	.18	.13
4-22-19	.19	.17	6-20-12	.51	.45
5-29-19	.16	.14	8-16-12	1.14	.83
6-12-19	1.58	1.37	5-2-13	.29	.24
6-28-19	.41	.37	7-22-13	.18	.12
7-14-19	.80	.71	6-10-14	.26	.20
8-13-19	.08	.07	9-9-14	1.29	.91
5-13-20	.30	.26	5-25-15	.36	.30
6-7-20	.36	.32	6-5-15	.41	.35
7-11-20	.22	.20	7-17-15	.99	.76
5-27-21	.21	.19	7-4-16	.80	.60
4-16-22	.09	.07	8-6-16	.26	.20
4-5-24	.08	.06	9-9-16	.14	.10
6-29-24	.33	.29	4-17-17	.10	.05
8-15-24	.25	.22	8-6-17	.08	.05
6-4-25	.10	.09	5-17-18	.10	.07
6-17-25	.09	.07	6-4-18	.45	.33
4-30-29	.11	.10	5-6-19	.15	.12
6-17-29	.14	.12	6-9-19	.51	.42
5-13-30	.08	.07	7-3-19	.61	.47
6-13-30	.16	.13	5-11-20	.23	.15
7-17-30	.14	.12	6-30-20	.34	.29
4-1-32	.22	.19	7-13-20	.39	.34
4-21-32	.46	.41	6-14-21	.17	.13
5-6-32	.12	.10	8-31-21	.15	.10
5-26-32	.30	.26	9-2-21	.49	.40
4-2-37	.08	.06	7-28-22	1.15	.94
5-31-37	.60	.53	8-20-22	.43	.31
6-19-37	.66	.59	6-17-23	.18	.12
8-19-37	.49	.43	7-12-23	.23	.15
5-5-38	.11	.09	8-6-23	.09	.06
6-13-38	.17	.14	9-30-23	.47	.38
7-8-38	.14	.12	6-27-24	.38	.29
8-8-38	.07	.06	7-15-24	.31	.24
9-21-38	.60	.53	5-19-25	.56	.50
6-7-40	.13	.12	6-2-25	1.00	.76
8-26-40	.28	.24	6-16-25	.20	.13
			5-9-26	.46	.32
			7-23-26	.56	.48
			9-17-26	.98	.78
			5-20-27	.11	.06
			8-15-27	.09	.05

(continued on next page)

TABLE D-3 (continued)

Date of Storm	Run-off Volume in Inches — Conditions — Existing	Future	Date of Storm	Run-off Volume in Inches — Conditions — Existing	Future
	Maple River			Elliot Creek	
6-3-18	.43	.30	5-26-12	.19	.13
4-22-19	.27	.19	6-20-12	.52	.44
5-29-19	.22	.15	8-16-12	1.13	.88
6-12-19	1.70	1.20	5-2-13	.29	.23
6-28-19	.54	.39	7-22-13	.19	.12
7-14-19	1.00	.75	6-10-14	.27	.21
8-13-19	.11	.08	9-9-14	1.39	.90
5-13-20	.41	.29	6-5-15	.42	.34
6-7-20	.48	.34	7-17-15	1.05	.79
7-11-20	.31	.21	7-4-16	.84	.63
5-27-21	.29	.21	8-6-16	.27	.20
4-16-22	.11	.08	9-9-16	.15	.11
4-5-24	.10	.07	6-4-18	.49	.33
6-29-24	.44	.31	5-6-19	.16	.12
8-15-24	.34	.24	6-9-19	.54	.41
6-4-25	.14	.10	7-3-19	.64	.48
6-17-25	.11	.08	5-11-20	.24	.16
4-30-29	.15	.11	6-30-20	.35	.30
6-17-29	.19	.13	7-13-20	.40	.33
5-13-30	.10	.07	6-14-21	.18	.14
6-13-30	.21	.15	9-2-21	.51	.41
7-17-30	.19	.13	7-28-22	1.18	.97
4-1-32	.29	.21	8-20-22	.48	.30
4-21-32	.61	.44	6-17-23	.20	.13
5-6-32	.16	.12	7-12-23	.24	.17
5-26-32	.41	.29	9-30-23	.49	.38
4-2-37	.10	.07	6-27-24	.40	.28
5-31-37	.78	.57	7-15-24	.32	.24
6-19-37	.85	.62	5-19-25	.57	.50
8-19-37	.64	.46	6-2-25	1.06	.76
5-5-38	.15	.10	6-16-25	.21	.14
6-13-38	.23	.16	5-9-26	.50	.32
7-8-38	.19	.13	7-23-26	.57	.48
8-8-38	.09	.07	9-17-26	1.03	.78
9-21-38	.78	.57	5-20-27	.12	.08
6-7-40	.18	.13			
8-26-40	.37	.26			

Conversion to Peak Flows: The calculated flood volumes were converted to peak flows at selected "master" cross-sections on the tributaries. This conversion was made by constructing average flood volume-peak flow relationships on the Little Sioux and Maple Rivers and the West Fork from the stream flow records available and entering these relationships with the calculated or observed volumes in the flood series. An average volume-peak flow relationship was calculated for Elliott Creek on the basis of unit discharges per square mile observed from the adjacent gaged areas.

Calculation of Areas Inundated: At the beginning of the survey, the Flood Damage Appraisers, the Sedimentation Specialists, and the Survey Engineers selected cross-sections and ranges to be used jointly for flood damage, sedimentation and hydrologic analysis. The primary ranges, which were used in the sedimentation study and the flood damage appraisal, were located approximately six miles apart. These, along with two intermediate cross-sections, thus making the cross-sections approximately two miles apart, were used in the hydrologic analysis. The field surveys for these sections were made by a mobile survey party.

Before using these cross-sections, each section was inspected in the field in order to determine cover, feasibility as a streamflow rating section, and other physical factors which would have a bearing on the flow at the particular section.

The profiles of the streams were obtained by levelling between the cross-sections.

The principal types of cover on the flood plain are grain, corn, pasture, and weeds.

The following table shows the estimated values of the roughness factor "n", used according to cover and depth. These values were established for average conditions when the corn would be about 3 or 4 feet high, at about the middle of the growing season.

Table D-4 - Variation of "n" for flood stages according to various cover

Depth in Feet	Grain	Corn	Pasture	Weeds
Up to 1	.08	.08	.05	.10
1-2	.075	.08	.045	.085
2-3	.065	.08	.04	.075
3-4	.05	.08	.035	.06
4 and over	.035	.05	.03	.045

An "n" of .04 was used for channel flow at all stages.

In computing the theoretical discharge by Mannings formula, the cross-section was divided into sections according to the cover and the values of "n" used as per Table D-4. To obtain the combined discharge,

TABLE D-5. CALCULATION OF DISCHARGE AT R-O WEST FORK

$S = .00690$

$S^{\frac{1}{2}} = .0263$

$$V = \frac{1.486\ R^{2/3}\ S^{\frac{1}{2}}}{n}$$

$Q = AV$

Gage height	Depth above bank flow	Flooded width in feet Left	Flooded width in feet Right	Area sq. ft.	Wetted perimeter P	Hydraulic radius R	R 2/3	Roughness factor n	Velocity ft./sec. V	Discharge cu.ft/sec. Q		EQ
15				896	97	9.23	4.400	.04	4.31	3860		
16				987	101	9.77	4.570	.04	4.47	4420		
17				1082	106	10.24	4.716	.04	4.62	4990		
18				1185	115	10.30	4.734	.04	4.63	5470		
19				1295	121	10.72	4.862	.04	4.75	6150		
20				1405	122	11.51	5.098	.04	4.98	7000		
21				1515	123	12.33	5.337	.04	5.23	7930		
22				1625	124	13.10	5.557	.04	5.43	8830		
16LL												3860
16LR	1	535		283	535	0.53	0.655	0.080	0.322	91	91	4511
17LL	1	254		253	254	1.00	1.000	0.080	0.492	124		
17LR	2	785		928	785	1.18	1.117	0.075	0.585	543	667	5657
18LL	2	262		508	262	1.94	1.556	0.080	0.763	388		
18LR	3	1175		1936	1175	1.65	1.394	0.065	0.843	1635	2023	7493
19LL	3	291		785	291	2.69	1.924	0.080	0.945	743		
19LR	4	1635		3448	1635	2.11	1.645	0.050	1.295	4470		
19R	1		360	208	362	0.59	0.703	0.080	0.346	72	5282	11432
20LL	4	315		1090	315	3.47	2.292	0.060	1.500	1640		
20LR	5	1635		5083	1635	3.12	2.135	0.035	2.400	12200		
20R	2		710	826	712	1.16	1.104	0.080	0.542	447	14287	21287
21LL	5	330		1415	330	4.30	2.644	0.050	2.080	2940		
21LR	6	1635		6718	1635	4.10	2.562	0.035	2.870	19300		
21R	3		1020	1701	1022	1.66	1.402	0.080	0.688	1170	23410	31340
22 LL	6	345	1755	1755	345	5.10	2.963	0.050	2.330	4080		
22 LR	7	1635		8353	1635	5.22	3.009	0.035	3.370	28200		
22 R	4		1104	2777	1107	2.53	1.857	0.060	1.215	3380	35660	44490

LL = Pasture and weeds
LR = Grain (clover)
R = Corn

the discharges in each of the divisions of the cross-section at corresponding stages were added together. This procedure was used instead of applying one value of "n" for all stages and cover conditions.

From these calculations, discharges for corresponding stages were plotted to form a rating curve, and points were plotted to show flooded width for each stage. Sample calculations are shown for R-0 (Figure D-5) on West Fork in Table D-5 and the graphs are shown in Figure D-6.

When calculations were completed for each cross-section, the sections were weighted according to the length of channel they represented. The length of channel multiplied by the flooded width for any stage gave the area flooded at the section being considered. Concordant flows throughout the stream length were set up in the ratio of the drainage areas to the o.6 power i.e. $\frac{Q_1}{Q_2} = \left[\frac{A_1}{A_2}\right]^{.6}$ These calculations are shown in Table D-6. It was at first assumed that the six flows shown this table would be sufficient to cover the range of floods in the evaluation series. However, it was discovered that due to the variation in topography of the flooded area many intermediate flows were required. In order to determine accurately the relation between stage and area inundated, Table D-7 was prepared. On each of the watersheds except Elliott Creek it was necessary to segregate certain reaches of the flood plain because of the great difference in flood damages. For this reason Table D-7 is divided into two parts: the ranges R-0 to R-15 represent the lower portion of the flood plain and R-15 to R-30 the upper portion. This same procedure was followed for each of the watersheds considered.

The concordant stages at all cross-sections were used to determine the width of inundation at the cross-sections. The areas of overflow in the reaches between the cross-sections were then computed by multiplying the stream lengths between the cross-sections by the mean of the width of inundation at the ends of the reaches. The inundated areas in all of the reaches were then totaled to determine the area inundated by floods of different magnitude. The areas inundated were plotted against the selected peak stages at the master section so that the area inundated by a flood of any magnitude could be quickly determined. Figures D-7 through D-11 show the discharge-area inundated relations for the Little Sioux, Maple, West Fork, and Elliott Creek.

As explained in Appendix B the area inundated-flood magnitude curve was used to determine the area of overflow by every flood of the evaluation series. This enables the damage to be estimated for each flood.

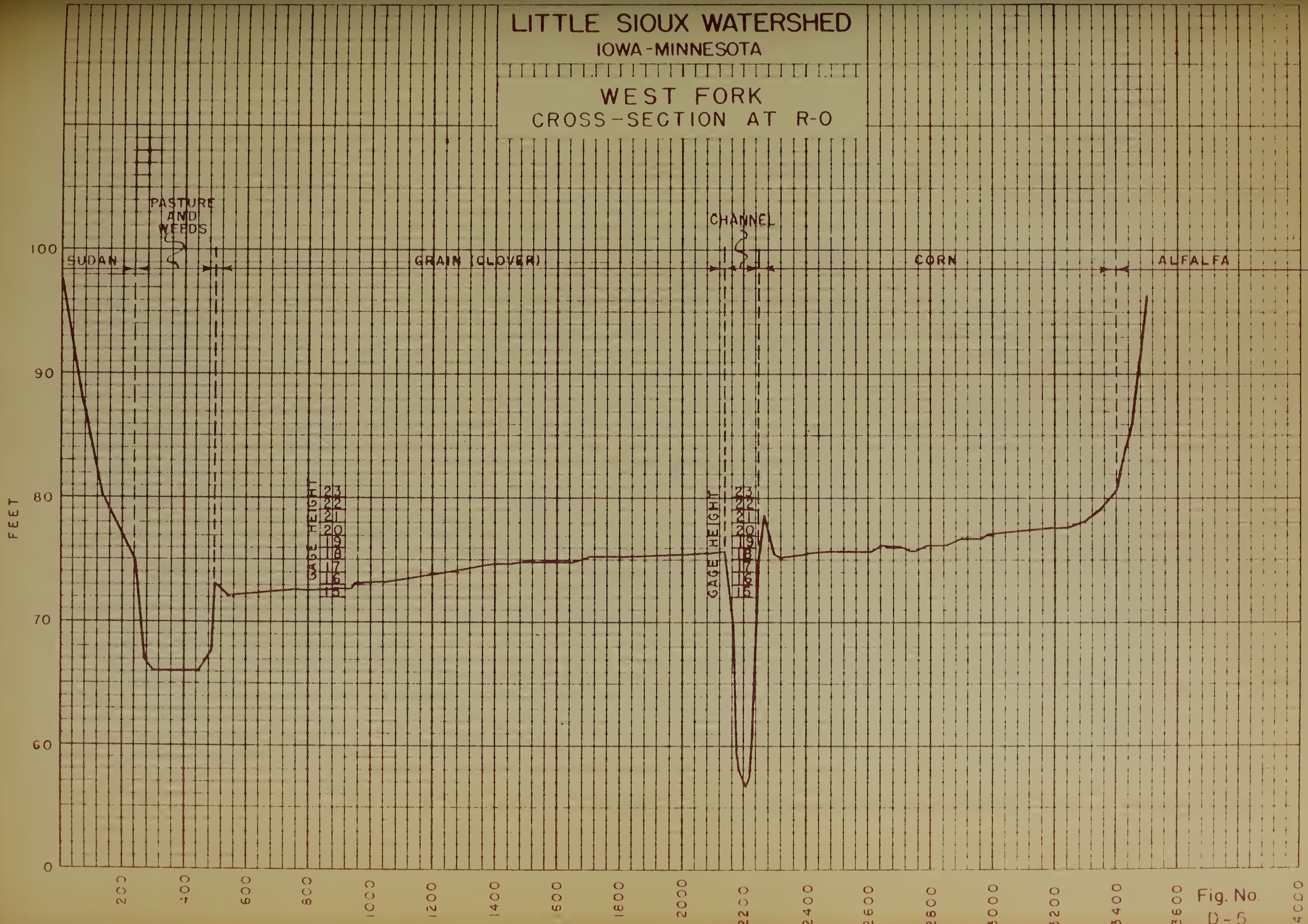

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
WEST FORK
CROSS-SECTION AT R-O
PASTURE AND WEEDS
SUDAN
GRAIN (CLOVER)
CHANNEL
CORN
ALFALFA
GAGE HEIGHT
23
22
21
20
19
18
17
16
15
GAGE HEIGHT
23
22
21
20
19
18
17
16
15
FEET
100
90
80
70
60
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
4000

Fig. No.
D-5

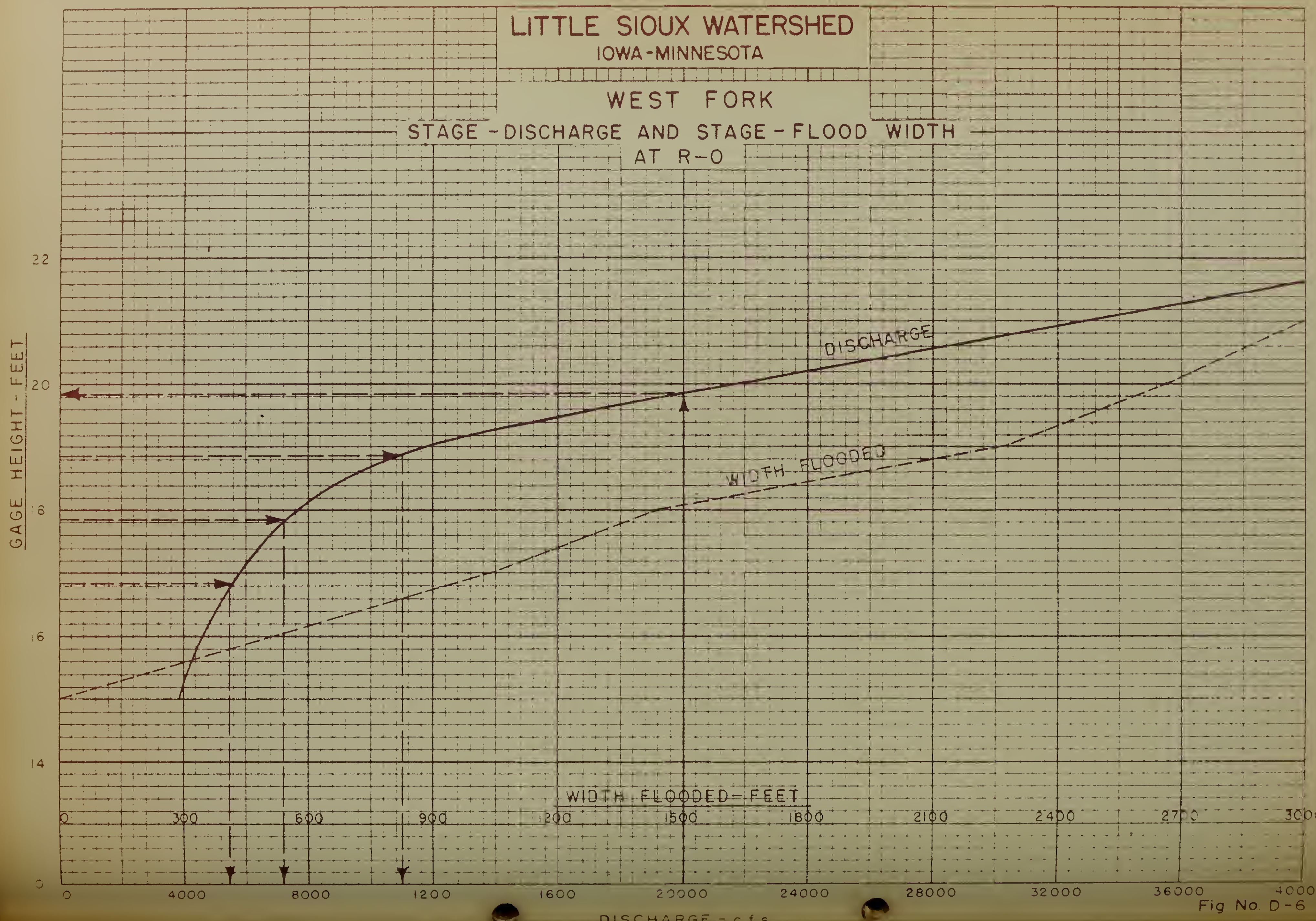

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
WEST FORK
STAGE - DISCHARGE AND STAGE - FLOOD WIDTH
AT R-O
GAGE HEIGHT - FEET
DISCHARGE - c.f.s.
WIDTH FLOODED - FEET
DISCHARGE
WIDTH FLOODED
0
14
16
18
20
22
0
4000
8000
1200
1600
20000
24000
28000
32000
36000
40000
0
300
600
900
1200
1500
1800
2100
2400
2700
3000

Fig. No. D-6

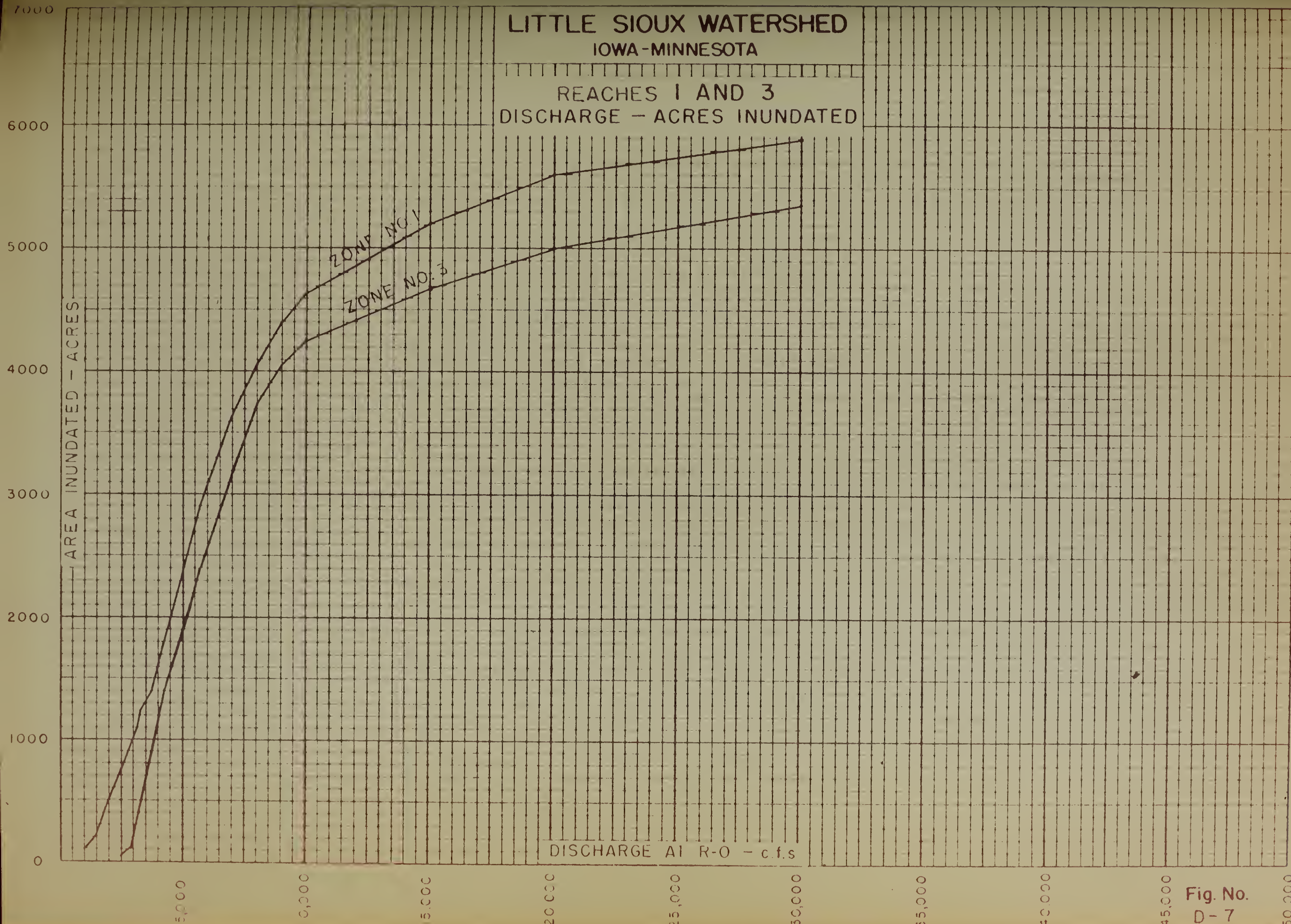
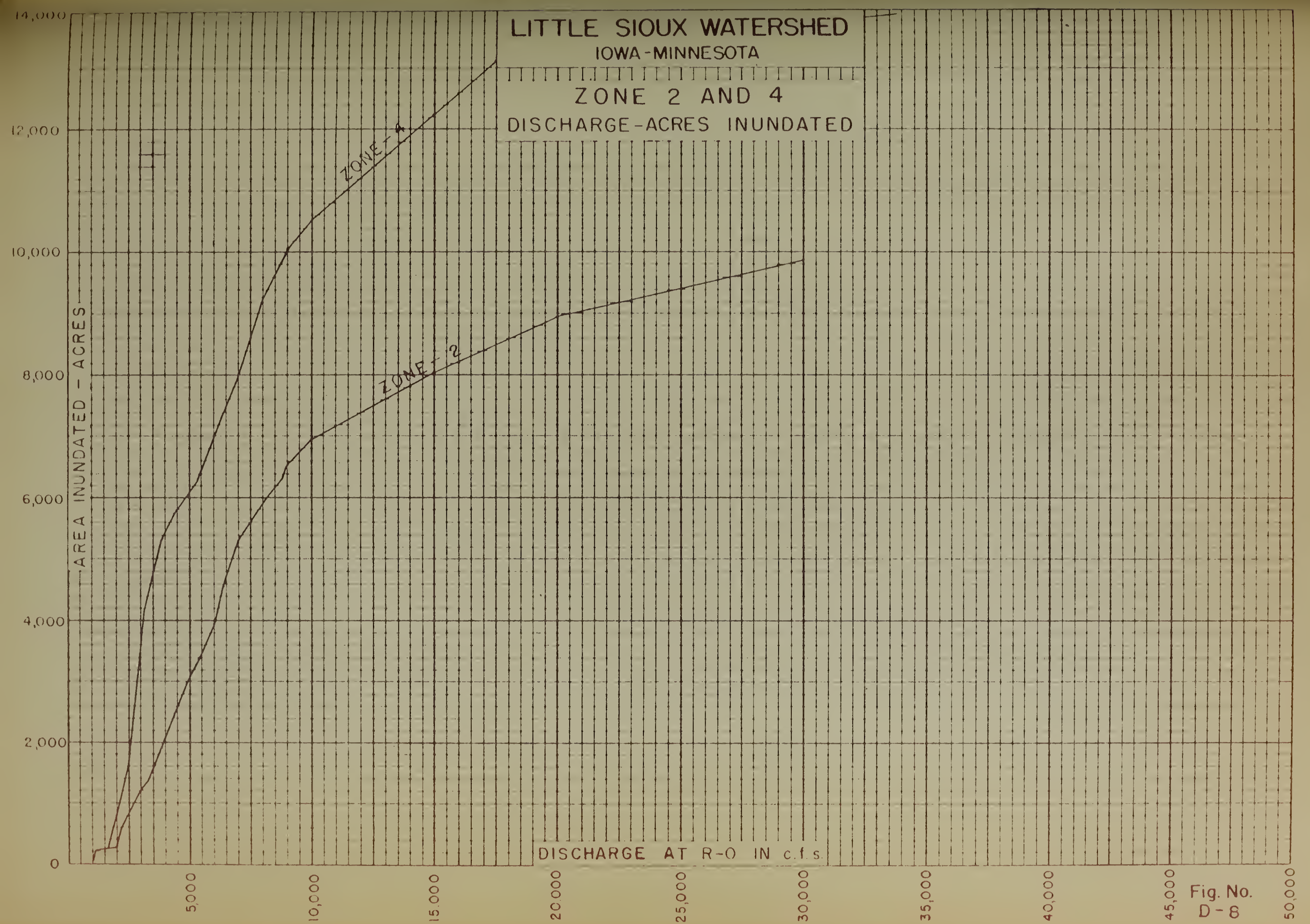
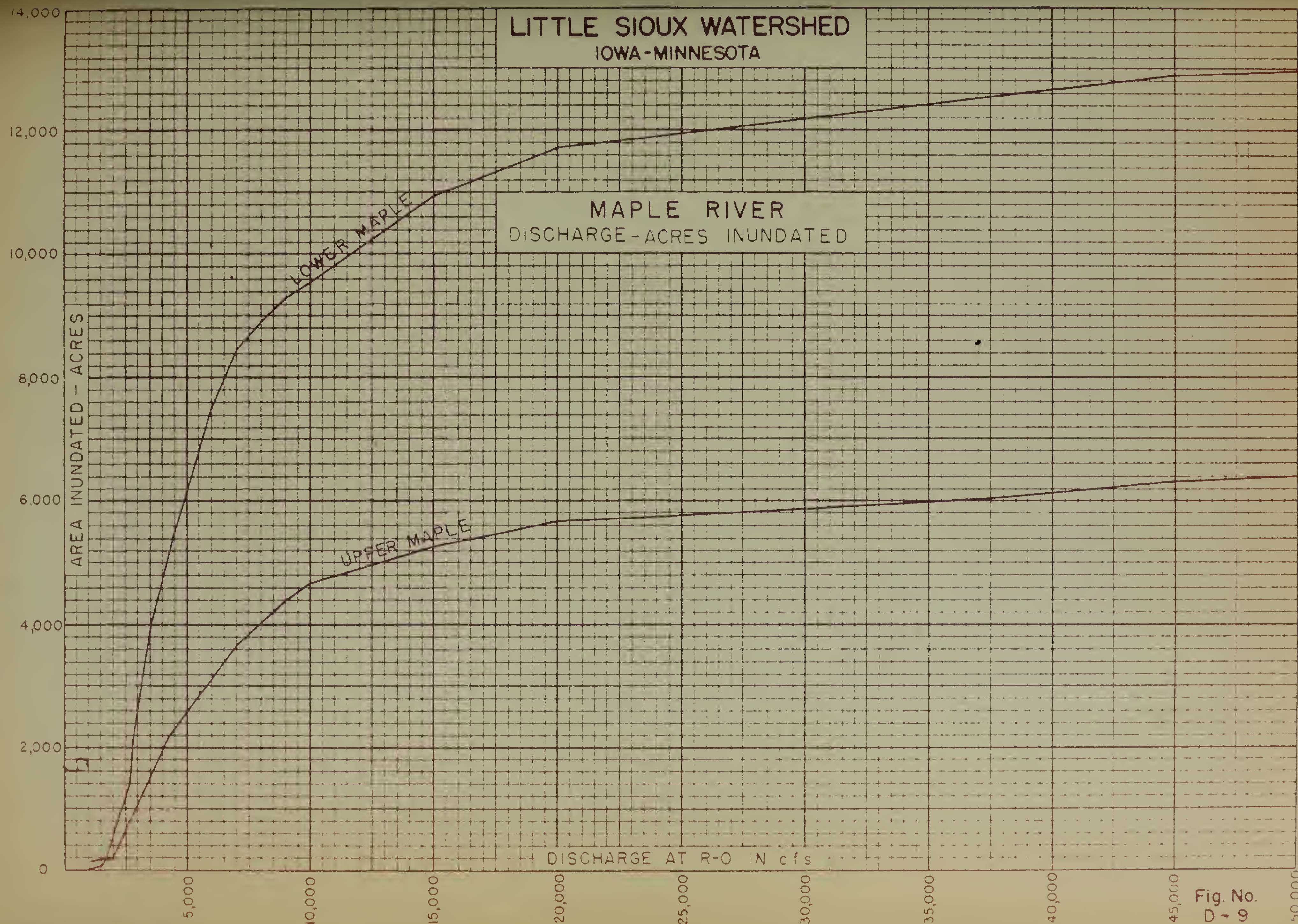

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
REACHES 1 AND 3
DISCHARGE - ACRES INUNDATED
ZONE NO. 1
ZONE NO. 3
AREA INUNDATED - ACRES
DISCHARGE AT R-O - c.f.s
0
1000
2000
3000
4000
5000
6000
7000
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000

Fig. No.
D-7


LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
ZONE 2 AND 4
DISCHARGE-ACRES INUNDATED
ZONE - 4
ZONE - 2
AREA INUNDATED - ACRES
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
DISCHARGE AT R-O IN c.f.s.
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
Fig. No. D-8


LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
MAPLE RIVER
DISCHARGE-ACRES INUNDATED
LOWER MAPLE
UPPER MAPLE
AREA INUNDATED - ACRES
DISCHARGE AT R-O IN cfs
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
Fig. No.
D-9

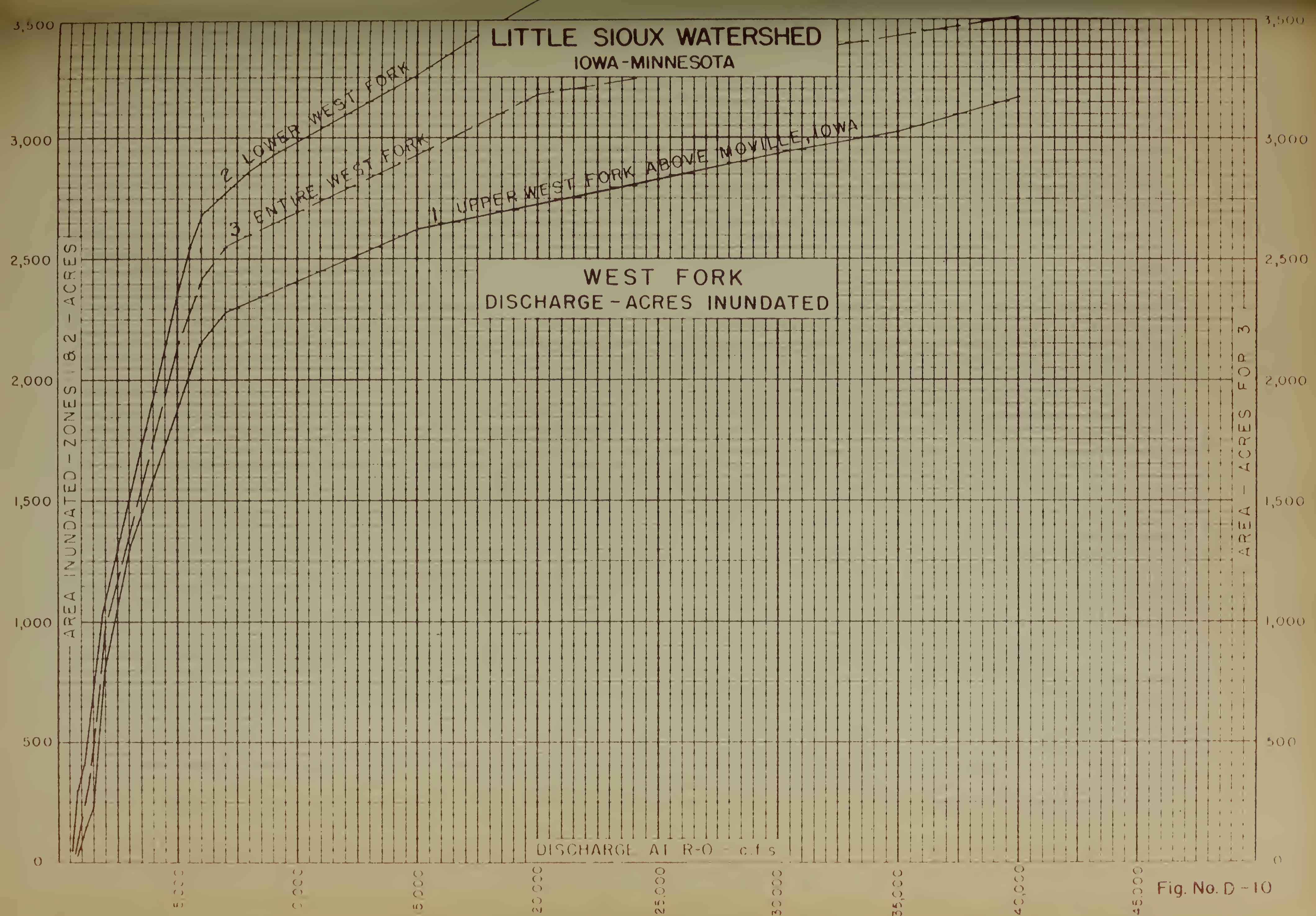

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
WEST FORK
DISCHARGE - ACRES INUNDATED
1 UPPER WEST FORK ABOVE MOVILLE, IOWA
2 LOWER WEST FORK
3 ENTIRE WEST FORK
AREA INUNDATED - ZONES 1 & 2 - ACRES
AREA - ACRES FOR 3
DISCHARGE AT R-0 - c.f.s.
0
500
1,000
1,500
2,000
2,500
3,000
3,500
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000

Fig. No. D-10

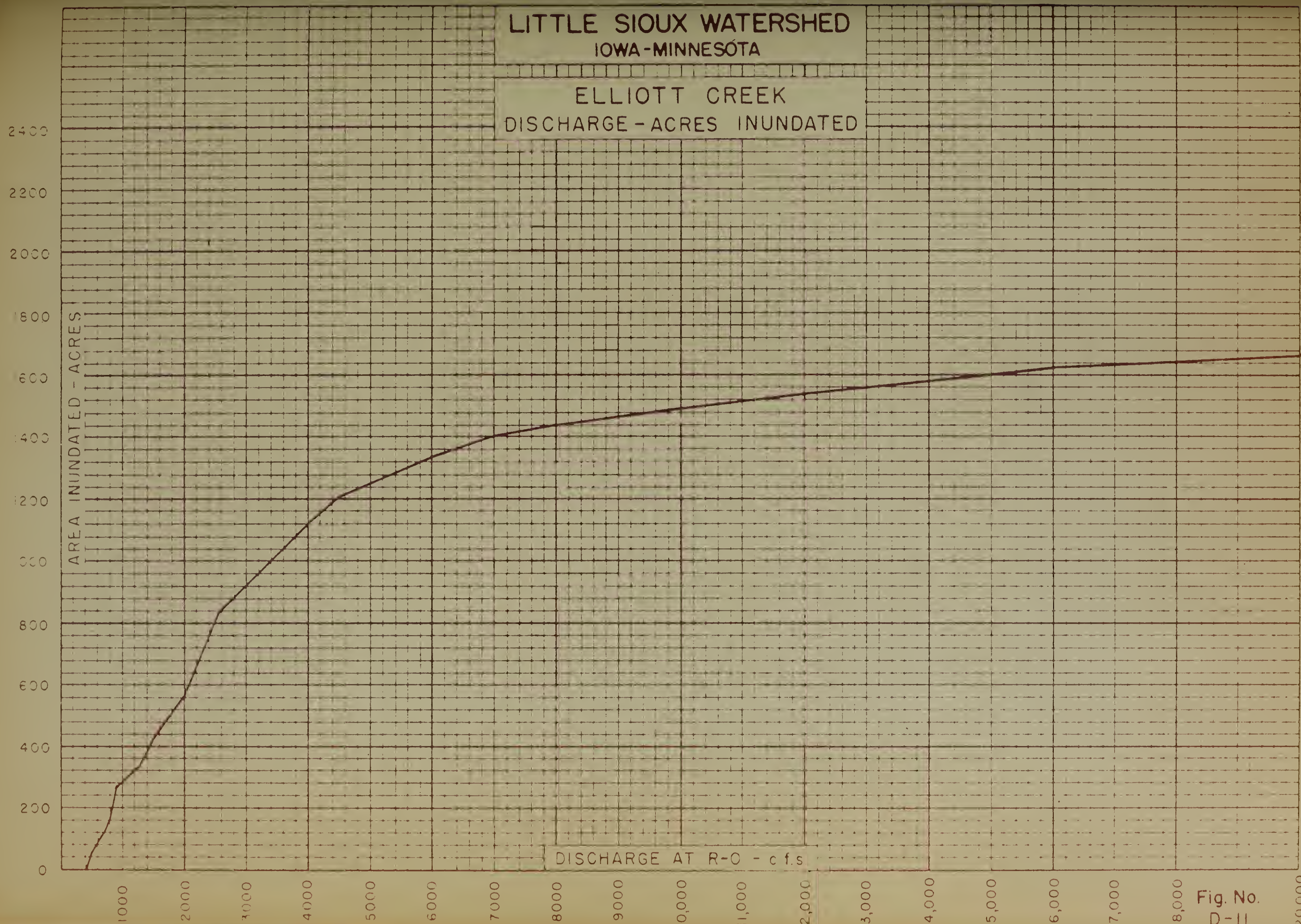

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
ELLIOTT CREEK
DISCHARGE - ACRES INUNDATED
AREA INUNDATED - ACRES
DISCHARGE AT R-C - c.f.s.
0
200
400
600
800
1200
1400
1600
1800
2000
2200
2400
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
20,000
Fig. No. D-11

TABLE D-6. DETERMINATION OF CONCORDANT FLOWS ON WEST FORK

Section	Drainage Area sq. mi.	Ratio $\frac{A_1}{A_2}^{0.6}$	1000	2000	5000	10,000	20,000	40,000
R-0	388	1.000	1000	2000	5000	10000	20000	40000
R-2	381	1.010	992	1980	4960	9920	19800	39650
R-4	376	1.020	983	1962	4910	9830	19620	39250
R-6	369	1.030	972	1941	4860	9720	19410	38850
R-8	362	1.044	960	1918	4800	9600	19180	38400
R-10	356	1.055	950	1900	4750	9500	19000	38000
R-12	347	1.068	940	1875	4700	9400	18750	37500
R-15	271	1.245	805	1608	4025	8050	16080	32200
R-18	246	1.315	762	1520	3805	7620	15200	30400
R-21	235	1.350	742	1480	3710	7425	14800	29650
R-22	225	1.385	724	1445	3610	7240	14450	28900
R-24	168	1.718	584	1165	2915	5840	11650	23300
R-26	150	1.770	566	1130	2830	5660	11300	22600
R-29	145	1.800	557	1110	2780	5570	11100	22250
R-30	138	1.860	538	1075	2690	5380	10750	21500
R-32	44	3.690	271	544	1355	2710	5440	10840

TABLE D-7. DISCHARGE - AREA INUNDATED RELATION - WEST FORK

			600			700	2000			2200	7000			
Section	Ratio	Weight	Q	Flooded width ft.	Weighted width	800 900 1000	Q	Flooded width ft.	Weighed width	2400 2600 2800	Q	Flooded width ft.	Weighted width	8000 9000 10000
R-0	1.000	1.55	600	0	0	1100	2000	0	0	3000	7000	1350	2100	15000
R-2	1.010	1.57	595	0	0	1200	1981	0	0	3500	6950	0	0	20000
R-4	1.020	2.15	590	0	0	1300	1960	0	0	4000	6875	2240	4810	25000
R-6	1.030	2.24	583	0	0	1400	1945	260	582	4500	6800	1285	2870	30000
R-8	1.044	2.12	576	0	0	1500	1917	890	1890	5000	6720	1045	2220	35000
R-10	1.055	2.12	570	0	0	1600	1896	850	1800	5500	6650	1200	2550	40000
R-12	1.068	3.16	563	120	380	1700	1875	950	2980	6000	6560	1700	5340	
R-15	1.245	2.02	483	0	0	1800	1605	930	1880		5630	1590	3210	
		16.93			380	1900			9132				23100	
Average width					22				540				1365	
Acres flooded					45				1105				2800	
R-15	1.245	1.15	483	0	0		1605	930	1070		5630	1590	1830	
R-18	1.315	3.16	457	0	0		1520	630	1990		5330	810	2560	
R-21	1.350	3.34	445	0	0		1483	440	1470		5190	1002	3342	
R-22	1.385	2.70	433	0	0		1444	200	540		5060	800	2160	
R-24	1.718	2.36	350	0	0		1163	580	1370		4075	1390	3280	
R-26	1.770	2.13	339	0	0		1130	0	0		3960	420	896	
R-29	1.800	2.20	334	0	0		1111	355	782		3890	800	1760	
R-30	1.860	2.87	323	0	0		1076	0	0		3770	1040	2980	
		19.91			0				7222				18808	
Average width					0				363				946	
Acres flooded					0				876				2280	
Total acres flooded					45				1981				5080	

SECTION II - EFFECT OF PROGRAM ON SEDIMENT

Farmland Treatment Program

The effect of the proposed remedial program upon the quantity of sediment reaching the drainage ditches on the Missouri River alluvial plain was approximated by assuming that ten years after the program became effective the delivery of sediment to the ditches would be reduced by the same percentage as upland erosion; the reduction to take place uniformly through the ten-year period.

Effect of Program Upon Erosion

By a study of experimental results obtained at several Soil Conservation Experiment Stations and of other applicable information, an index of erosion was derived for each of the covers and practices existing, or to exist under the program, in the Little Sioux watershed. These indices represent the ratio of erosion for the given condition to erosion on fair native pasture. Table D-8 shows the indices adopted.

By weighting the erosion indices with the relative area of the represented condition existing in each delineation it was found that the program would reduce the soil lost from each by the following percentages:

Delineation	Percentage Reduction
9-B-1	55.0
9-B-2	43.7
9-C-2 and 3	68.0
11-C-2	68.0
11-C-3	68.0
11-D-1	66.0
11-D-2	71.8
11-D-3	76.0
150-C and D-1 and 2	42.0

Effect of Program Upon Delivery of Sediment to Second Order Streams

Given the estimated reductions in erosion it was assumed that the delivery of sediment to the second order streams would be reduced by the same percentages as erosion. The total deliveries of sediment for all the lands in Division A and B were then calculated for both present and contemplated conditions. In this way it was found:

1. That within Division A the delivery of sediment to second order streams would be reduced 49.6% by the farmland treatment program.
2. That within Division B the corresponding reduction would be 65.2%.

Major Gully Control Program

The major gully control program was designed to bring these gullies to a standstill. However, to insure a conservative estimate of benefits it was assumed that the major gullies will continue to discharge 10 percent of the sediment they now yield; that is the program was considered 90 percent effective.

TABLE D-8: RELATIVE VALUE OF EROSION FOR VARIOUS COVERS AND PRACTICES IN THE LITTLE SIOUX WATERSHED

	Present condition	Remedial Program: No supporting practice	Remedial Program: With contouring	Remedial Program: With terracing
Clean Tilled	17.00	15.34	6.14	3.84
Small Grain	5.79	5.79	5.30	1.44
Rotation Hay	2.30	2.30	2.30	.58
Permanent Hay	1.50	1.50		
Poor Tame Pasture	1.30	1.30		
Good Tame Pasture	.50	.50		
Poor Native Pasture	1.30	1.30		
Fair Native Pasture	1.00	1.00		
Good Native Pasture	.50	.50		
Grazed Woodland	.50	.50		
Protected Woodland	0	0		
Unproductive Land	12.00	12.00		
Idle Land	7.00	7.00		
Farmstead	5.00	5.00		
Roads	5.00	5.00		

APPENDIX D

SUPPLEMENT A

Infiltration Studies

Soils of major importance in the Little Sioux watershed are of the loess and drift character. For infiltration purposes, soils developed under similar conditions or soils with approximately the same characteristics were placed in the same category.

The soil groups sampled are given in Table DA-1. The dominating soil in each group is listed first and all infiltrometer runs for that classification were made on that particular soil type. Clarion Silt Loam is classed with the Loess soils in Group I, for infiltration purposes because similarity of surface conditions. A soil of this character would tend more toward the loess types than to the drift types.

Major land uses occurring at the present and those to be found under the recommended program are: clean tilled, small grain, legume meadow, and poor and good pasture. By obtaining the infiltration rates for the above land uses, evaluations for the recommended program could be made.

Soil type and land use complexes for which infiltration values were obtained are given in Table DA-2. Also given in this table are the conditions sampled by the F and FA type infiltrometer 1/ during the three seasons. The complexes sampled were chosen to enable easy interpolation of values for conditions that were not field determined.

As is shown in Table DA-2, the F type was used on three soils and only two cover conditions for each soil. The FA was used on six soils and a series of covers for each. The F was used only for the spring season; whereas the FA was used during the spring, summer and fall. Complete data were obtained in the spring, but only designated values were obtained for the summer and fall. By securing values on the selected complexes, values for the remaining conditions were interpolated.

The test plots were located on the sample farms used for other studies connected with the survey. More than one cover or soil was taken on the same farm if it was practical to do so. Past land use was also considered when determining plot locations.

The number of runs necessary to establish an acceptable infiltration value varied with the type of infiltrometer. Only four runs were made with the F; whereas the FA number required was determined by the standard error which was to be less than 20 percent of the mean. Some complex values do not meet this standard because of limitations on time and funds.

1/ The type FA infiltrometer plot is 12 inches wide and 18 inches long. The type F infiltrometer plot is 6 feet by 12 feet.

Table DA-1

Summary of Soil Types Classified as to Infiltration Characteristics

Soil Group	Soil Type
I	Marshall silt loam, Marshall silt loam (flat phase), Waukesha silt loam (B), Clarion silt loam.
II	Clarion loam
III	Knox silt loam
IV	Marshall silt loam (brown phase)
V	Webster silty clay loam, Marcus silty clay loam, Lamoure silty clay loam, Benoit silty clay loam, Wakesha silt loam (A), O'Neil loam, Sioux loam, Wabash silt loam.
VI	Clarion loam (steep phase), Clarion loam (rolling phase), Clarion fine sandy loam, Dickinson fine sandy loam, Pierce loam, Pierce fine sandy loam.

TABLE DA-2. INFILTRATION RATES (f_c) IN INCHES PER HOUR BY SOILS, SEASON, LAND USE AND TYPE OF INFILTROMETER.

Soils	Season	LAND USE							
		Corn		Small Grain	Legume Meadow		Grass Legume Meadow	Poor Pasture	Good Pasture
		FA	F	FA	FA	F	FA	FA	FA
Marshall silt loam	Spring	.395	.299		1.077	.990			
	Summer	.427		1.090	.931				
	Fall	.494		1.089	1.548				
Clarion loam	Spring	.685			1.112				
	Summer								
	Fall								
Knox Silt loam	Spring	.521	.352	.607	.704	.508	1.157	.565	.904
	Summer	.347							
	Fall								
Marshall silt loam (brown phase)	Spring	.381	.442			.486			
	Summer								
	Fall								
Webster silty clay loam	Spring	.396			1.371				
	Summer	.594			2.032				
	Fall								
Clarion loam (steep phase)	Spring	.455			1.771				
	Summer								
	Fall								

In Tables DA-3, DA-4, DA-5, DA-6, DA-7, DA-8, DA-9 and DA-10 are listed the individual terminal rainfall minus run-off values from the plots with their respective means, standard deviations, and standard errors. These are given by soil groups, land use, season, and type of infiltrometer.

For all complexes sampled, Ø curves were developed for both the F and FA types. Bases for these were the individual rainfall minus run-off curves.

To obtain a common starting point for all rainfall minus run-off curves of a given complex, it was necessary to extend all curves to a point equal to the time of the curve having the shortest elapsed time before run-off occurred. The highest rate of rainfall minus run-off to which these curves could be extended was the highest probable intensity rain that can be expected to occur on the watershed. This intensity was established at 6.00 inches per hour. From these rainfall minus run-off curves a composite was made.

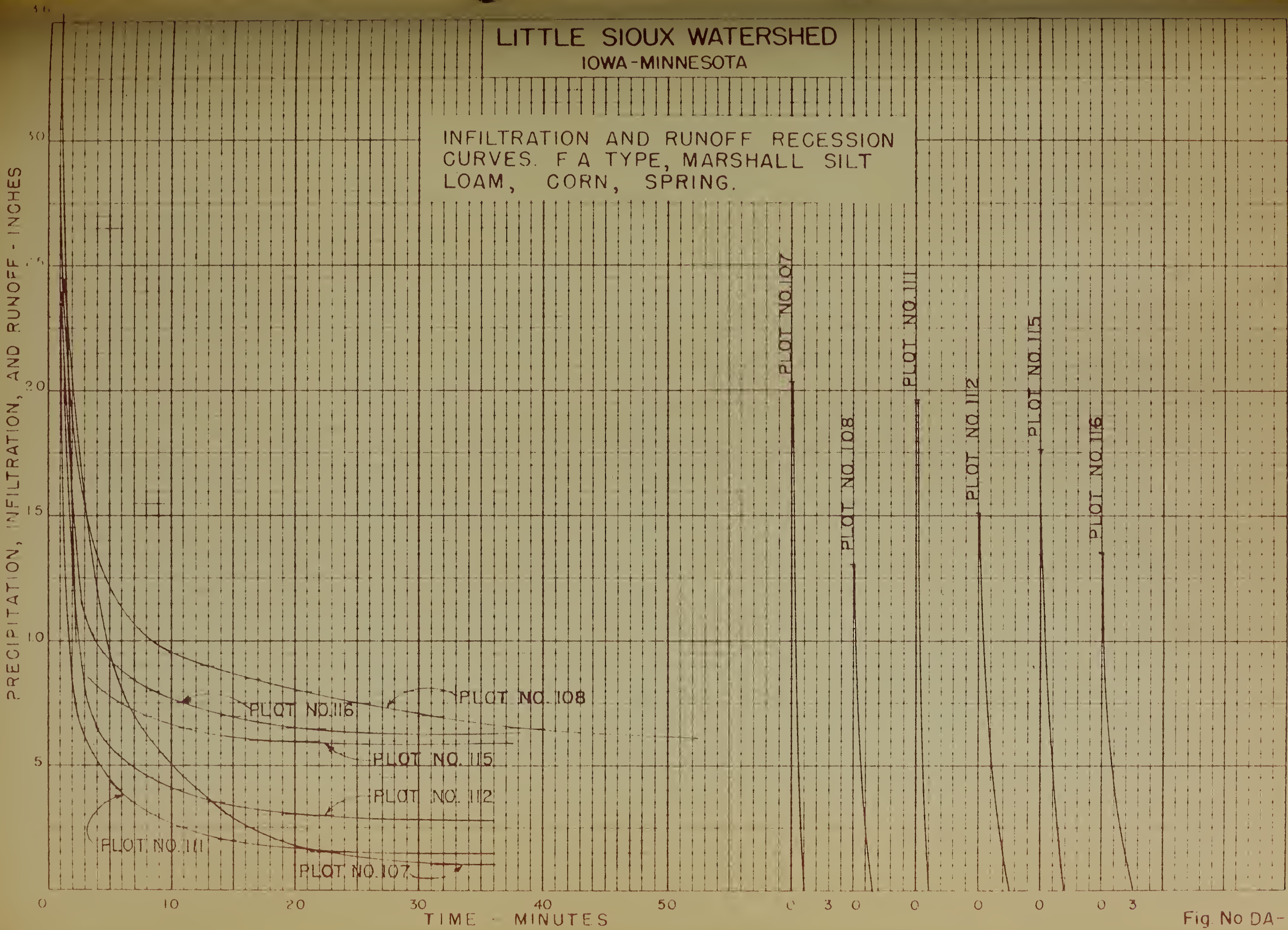
The sample Ø curve calculation shown is for the Marshall silt loam-corn-spring complex. The six individual rainfall minus run-off curves and recession curves, Figure DA-1, were drawn from data taken in the field. Infiltration values of each curve at a designated time are read and entered in Table DA-11. Average rainfall and run-off values are then obtained. Average rates of run-off are then calculated for the various times as given at top of Figure DA-2. Mass run-off values are entered at bottom of page in line "Q".

The volume of run-off recession curves was determined in the following manner. By ocular inspection, one curve, No. 115, was chosen as being typical. This curve was usually one of high rate and of a good length in time. This was plotted to a suitable scale in Figure DA-2. It was then desired that the remaining curves should intersect this base curve at their individual midpoints. The midpoint of the rate axis was determined for a curve, and this was located on the base curve at that point. All the other points of that curve were then located by merely off-setting them to the corresponding position of midpoint. This gave a well-grouped set of recession curves through which an average recession curve could easily be drawn.

Cumulative volumes, calculated for the average recession curve, were plotted by intensity and volume (Figure DA-3). From this curve, volumes were read which corresponded to the time and run-off rates as calculated at top of Figure DA-2. These $Q + Q_2$ values were added to the respective run-off values in line "Q", changes to rates "q" and subtracted from the precipitation "P" to get the Ø values. These, with the average run-off and infiltration values, were plotted and curved in Figure DA-3.

The following is the procedure used in developing Ø curves which were applied to the storm diagrams discussed in Appendix D.

The results of field infiltrometer runs, in terms of minimum rainfall minus run-off rates, were set up on the left side of Table DA-12. Where



LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
INFILTRATION AND RUNOFF RECESSION CURVES. F A TYPE, MARSHALL SILT LOAM, CORN, SPRING.
PLOT NO.107
PLOT NO.108
PLOT NO.111
PLOT NO.112
PLOT NO.115
PLOT NO.116
PRECIPITATION, INFILTRATION, AND RUNOFF - INCHES
TIME - MINUTES
0
10
20
30
40
50
5
1.0
1.5
2.0
3.0

Fig. No DA-1

LITTLE SIOUX RIVER - IOWA
FLOOD SURVEY

∅ CALCULATION

FA TYPE INFILTROMETER

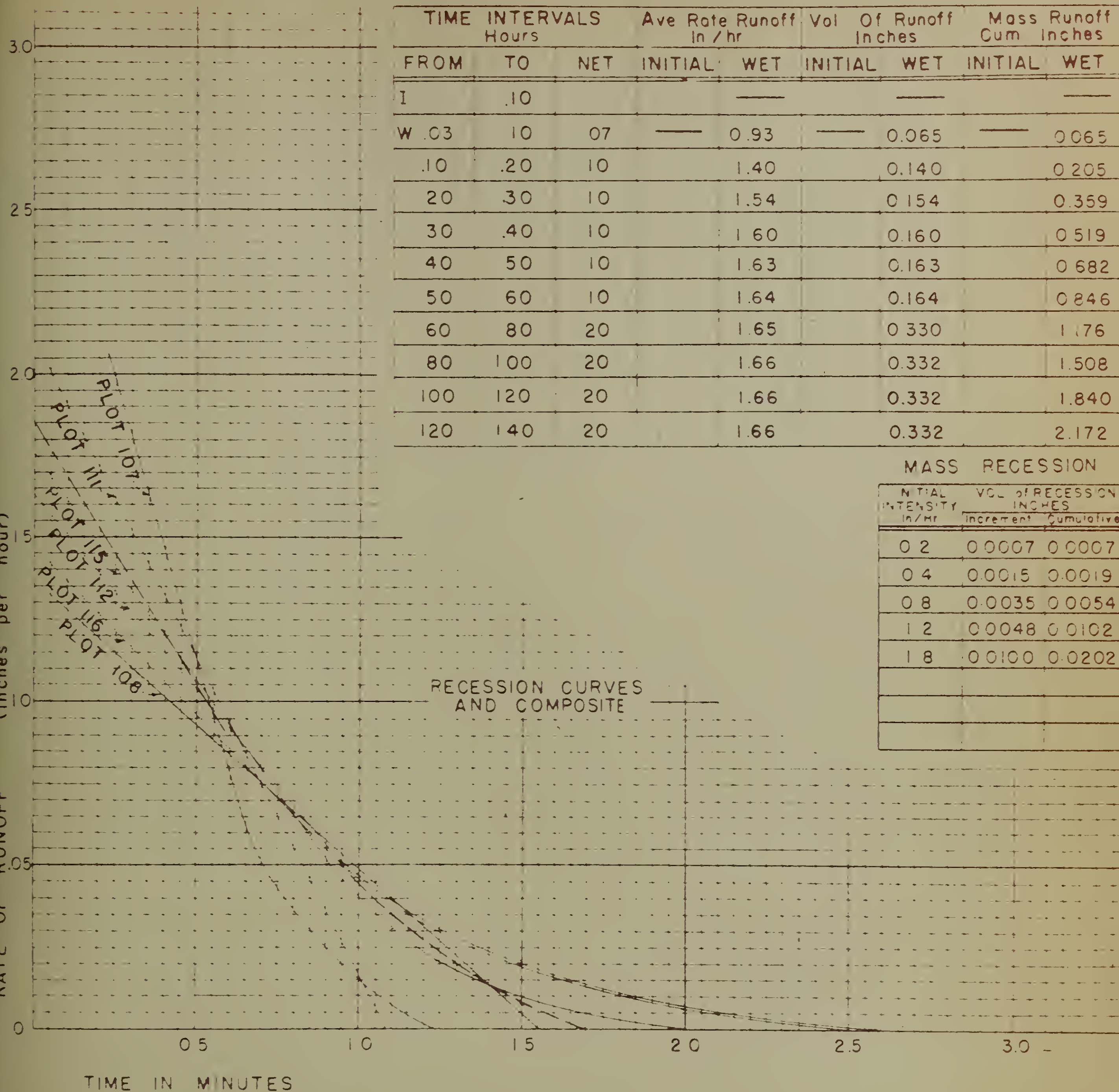
Soil Marshall Silt Loam Cover Corn Season Spring

CUMULATIVE OUTFLOW, Q, (Runoff During Rain)

TIME INTERVALS Hours			Ave Rate Runoff In/hr		Vol Of Runoff Inches		Mass Runoff Cum Inches	
FROM	TO	NET	INITIAL	WET	INITIAL	WET	INITIAL	WET
I	.10			——		——		——
W .03	.10	.07	——	0.93	——	0.065	——	0.065
.10	.20	.10		1.40		0.140		0.205
.20	.30	.10		1.54		0.154		0.359
.30	.40	.10		1.60		0.160		0.519
.40	.50	.10		1.63		0.163		0.682
.50	.60	.10		1.64		0.164		0.846
.60	.80	.20		1.65		0.330		1.176
.80	1.00	.20		1.66		0.332		1.508
1.00	1.20	.20		1.66		0.332		1.840
1.20	1.40	.20		1.66		0.332		2.172

MASS RECESSION

INITIAL INTENSITY In/Hr	VOL of RECESSION INCHES Increment	Cumulative
0.2	0.0007	0.0007
0.4	0.0015	0.0019
0.8	0.0035	0.0054
1.2	0.0048	0.0102
1.8	0.0100	0.0202



DERIVATION OF ∅

INITIAL RUN										Time Hrs	WET RUN									
.1	.2	.3	.4	.5	.6	.8	1.0	1.2	1.4		.1	.2	.3	.4	.5	.6	.8	1.0	1.2	1.4
										Q	0.06	0.20	0.36	0.52	0.68	0.85	1.18	1.51	1.84	2.17
										Qr	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
										Q+Qr	0.07	0.21	0.38	0.54	0.70	0.87	1.20	1.53	1.86	2.19
										P	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05
										q	0.70	1.05	1.27	1.35	1.40	1.45	1.50	1.53	1.55	1.56
										∅	1.35	1.00	0.78	0.70	0.65	0.60	0.55	0.52	0.50	0.49

Fig. No. DA-2

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA

CURVES OF RATE OF INFILTRATION, RATE OF RUNOFF, MASS RUNOFF, VOLUME OF RUNOFF RECESSION, AND Ø FOR MARSHALL SILT LOAM, F A TYPE, CORN, SPRING.

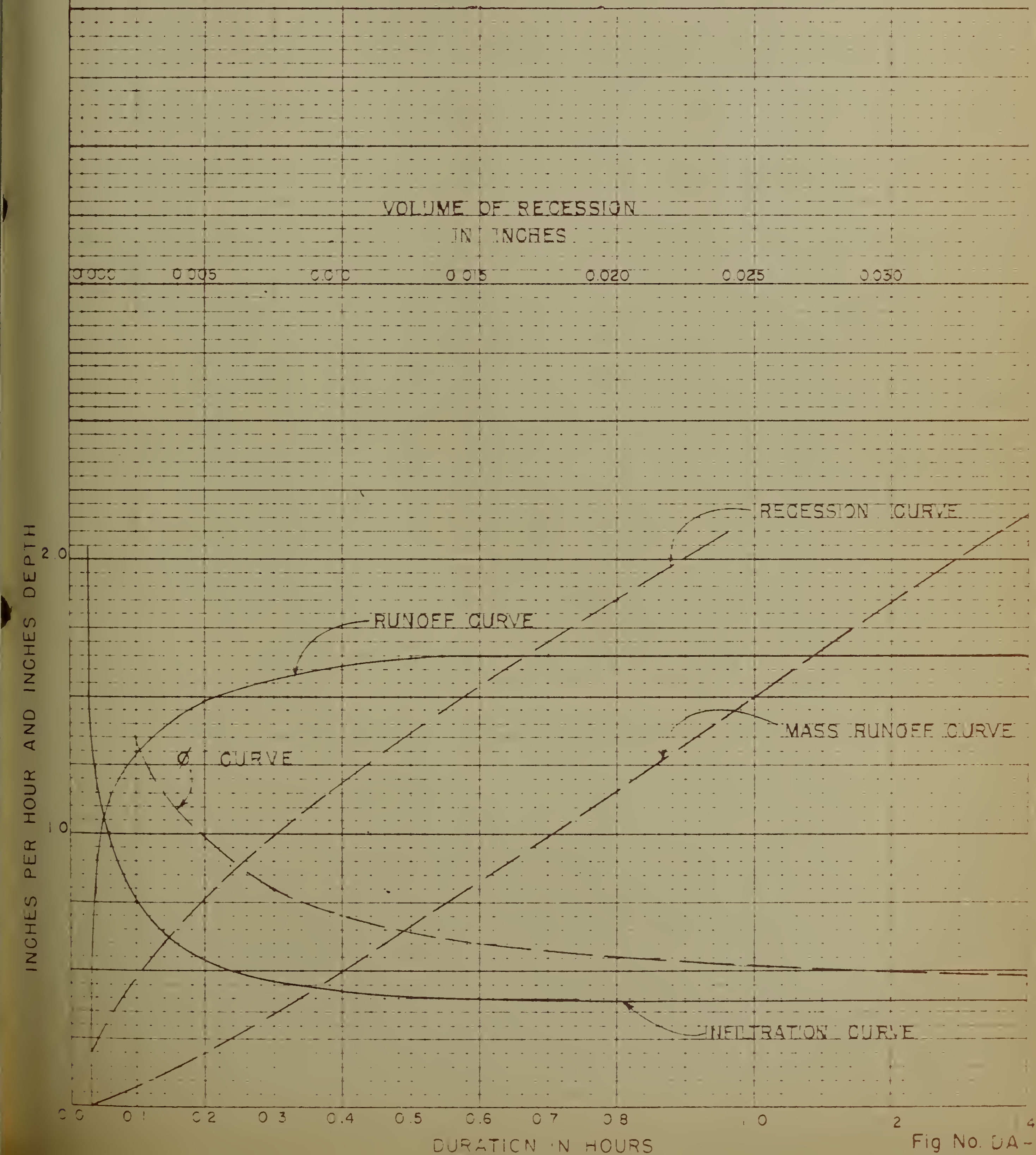


Fig No. DA-3

TABLE DA-3. INFILTRATION RATES (f_c) OF INDIVIDUAL PLOTS FOR F INFILTROMETER BY VEGETAL COVER AND SOIL TYPE

	Vegetal Cover	
	Corn	Legume
	Marshall silt loam- spring season rate in inches per hour	
	.227	.886
	.281	.618
	.389	1.163
	.299	1.295
No. of plots	4	4
Mean	.2990	.9905
	Marshall silt loam (brown phase) - spring season, rate in inches per hour	
	.421	.497
	.436	.405
	.223	.627
	.686	.413
No. of plots	4	4
Mean	.4415	.4855
	Knox silt loam - spring season rate in inches per hour	
	.373	.478
	.490	.299
	.238	.594
	.306	.663
No. of plots	4	4
Mean	.3518	.5085

TABLE DA-4. INFILTRATION RATES (f_c) OF INDIVIDUAL PLOTS FOR FA INFILTROMETER BY VEGETAL COVER AND SOIL TYPE

	Vegetal Cover
	Corn
	Marshall silt loam (brown phase) - spring season, rate in inches per hour
	.652
	.487
	.335
	.223
	.498
	.430
	.240
	.271
	.290
No. of plots	9
Mean	.3807
Standard deviation	±.1449
Standard error	±.0483

TABLE DA-5. INFILTRATION RATES (f_c) OF INDIVIDUAL PLOTS FOR FA INFILTROMETER BY VEGETAL COVER AND SOIL TYPE

	Vegetal Cover	
	Corn	Good Pasture
	Clarion (steep phase) - spring season rate in inches per hour	
	.939	1.385
	.428	1.408
	.466	1.644
	.396	1.489
	.512	2.815
	.178	1.420
	.267	2.238
No. of plots	7	7
Mean	.4551	1.7713
Standard deviation	±.2837	± .5467
Standard error	±.1072	± .2070

TABLE DA-6. INFILTRATION ON RATES (f_c) OF INDIVIDUAL PLOTS FOR FA INFILTROMETER BY VEGETAL COVER AND SOIL TYPE

	Vegetal Cover					
	Corn	Small Grain	Legume Meadow	Grass-legume Meadow	Poor Pasture	Good Pasture
			Knox silt loam - spring season rate in inches per hour			
	.527	1.099	.558	.385	.402	.797
	.547	.136	.782	1.228	.310	.487
	.584	.526	.660	.543	.445	.505
	.605	.627	.510	.539	1.289	.618
	.473	.649	.880	1.570	.827	1.461
	.390	.583	.835	1.298	1.090	1.300
		.629		1.688	.139	1.076
				2.005	.260	.989
					.366	
					.525	
No. of plots	6	7	6	8	10	8
Mean	.5210	.6066	.7042	1.1570	.5651	.9041
Stand. dev.	±.0789	±.2809	±.1516	±.6037	±.3781	±.3645
Stand error	±.0035	±.1062	±.0619	±.2135	±.1194	±.1378
			Knox silt loam - summer season rate in inches per hour			
	.391			.426		
	.467			.601		
	.481			.393		
	.504			.707		
	.125			1.404		
	.116			1.383		
				1.218		
				1.427		
No. of plots	6			8		
Mean	.3473			.9449		
Stand. dev.	±.2688			±.5512		
Stand error	±.1097			±.1949		

TABLE DA-7. INFILTRATION RATES (f_c) OF INDIVIDUAL PLOTS FOR FA INFILTROMETER BY VEGETAL COVER AND SOIL TYPE

	Vegetal Cover		
	Corn	Small Grain	Legume Meadow
	Marshall silt loam - spring season rate in inches per hour		
	.111		1.044
	.614		1.091
	.140		.681
	.283		.468
	.590		1.612
	.631		1.564
No. of plots	6		6
Mean	.3948		1.0767
Standard deviation	±.2453		± .6860
Standard error	±.1000		± .2801
	Marshall silt loam - summer season rate in inches per hour		
	.548	.753	1.030
	.232	1.036	.913
	.233	1.573	1.010
	.274	1.038	1.432
	.721	.821	.970
	.552	1.320	.232
No. of plots	6	6	6
Mean	.4267	1.0902	.9312
Standard deviation	±.3106	± .4622	±.5820
Standard error	±.1268	± .1887	±.2376

TABLE DA-8. INFILTRATION RATES (f_c) OF INDIVIDUAL PLOTS FOR FA INFILTROMETER BY VEGETAL COVER AND SOIL TYPE

	Vegetal Cover		
	Corn	Small Grain	Legume Meadow
	Marshall silt loam - fall season rate in inches per hour		
	.496	.686	1.500
	.604	1.035	2.145
	.446	.958	1.728
	.335	2.023	1.137
	.447	.663	1.506
	.568	.811	1.096
	.549	1.381	1.618
	.401	.664	2.217
	.521	.514	1.080
	.568	1.337	1.306
		.502	1.476
		1.966	1.767
		1.622	
		.689	
		1.479	
No. of plots	10	15	12
Mean	.4935	1.0887	1.5480
Standard deviation	±.0839	± .5110	± .3753
Standard error	±.0265	± .1319	± .1083

TABLE DA-9. INFILTRATION RATES (f_c) OF INDIVIDUAL PLOTS FOR FA INFILTROMETER BY VEGETAL COVER AND SOIL TYPE

	Vegetal Cover	
	Corn	Legume Meadow
	Clarion silt loam - spring season rate in inches per hour	
	.513	1.389
	.590	.840
	.572	.510
	.885	.930
	.866	1.406
	.685	1.600
No. of plots	6	6
Mean	.6852	1.1125
Standard deviation	±.2395	± .6241
Standard error	±.0978	± .2548

TABLE DA-10. INFILTRATION RATES (f_c) OF INDIVIDUAL PLOTS FOR FA INFILTROMETER BY VEGETAL COVER AND SOIL TYPE

	Vegetal Cover: Corn	Vegetal Cover: Legume
	Webster silty clay loam - spring season, rate in inches per hour	
	.258	.700
	.534	1.519
	.330	1.508
	.282	1.090
	.270	1.930
	.404	1.480
No. of plots	6	6
Mean	.3963	1.3712
Standard deviation	±.1958	± .6324
Standard error	±.0799	± .2582
	Webster silty clay loam - summer season, rate in inches per hour	
	.471	2.040
	.143	1.632
	.540	1.779
	.627	2.163
	.812	2.940
	.970	1.640
No. of plots	6	6
Mean	.5938	2.0323
Standard deviation	± .4289	± .6844
Standard error	± .1751	± .2794

TABLE DA-11. COMPOSITE INFILTRATION CALCULATION, FA TYPE INFILTROMETER

Initial

Soil Marshall silt loam . Cover corn Season spring Wet X

Plot No.	Rain intensity in/hr.	RAINFALL MINUS RUN-OFF AT VARIOUS TIMES FROM START OF RAIN IN HOURS AND MINUTES													
		HOURS													
		0.02	0.05	0.10	0.15	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2
		MINUTES													
		1	3	6	9	12	18	24	30	36	42	48	54	60	72
107	2.149	2.45	1.50	0.77	0.76	0.40	0.22	0.13	0.11	0.11	0.11	0.11	0.11	0.11	0.11
108	1.924	2.89	1.54	1.12	0.99	0.92	0.83	0.76	0.71	0.66	0.62	0.61	0.61	0.61	0.61
111	2.093	2.09	0.58	0.39	0.29	0.23	0.18	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14
112	1.793	2.30	0.80	0.51	0.43	0.37	0.31	0.29	0.28	0.28	0.28	0.28	0.28	0.28	0.28
115	2.350	2.35	0.85	0.75	0.69	0.65	0.60	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
116	2.001	3.60	1.07	0.88	0.79	0.73	0.68	0.64	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Sum	12.310	15.68	6.34	4.42	3.95	3.30	2.82	2.56	2.46	2.41	2.37	2.36			
Mean	2.052	2.61	1.06	0.74	0.66	0.55	0.47	0.43	0.41	0.40	0.40	0.39			
Average run-off			0.99	1.31	1.39	1.50	1.58	1.62	1.64	1.65	1.65	1.66			

STATISTICAL ANALYSIS f_c DATA

Sum X^2	SE = SD $/\sqrt{n}$ $\pm$
$(\text{Sum } X)^2/n$	r = SD/0.2M
Sum x^2	n' = Required Number of plots
$(\text{Sum } x)^2/(n-1)$	
SD $\pm$	
G_V = (SD/M) 100	

both F and FA equipment was used on the same soil and cover, the values were plotted to determine the relation between the minimum rates of the two sets of equipment (Figure DA-4). With this relation established all FA values were converted to F values as shown on the right side of Table DA-12. To determine the values for cover conditions on which no runs were made, the soils were set up on vertical lines (Figure DA-5) spaced so that the average of the f_c (spring) values of corn and legume would fall in a straight line. This was done so that if the ratios between cover types varied between soil types, the error in determining intermediate values would not be applied to only one cover but would be more evenly distributed to all covers. The f_c values in Table DA-12 were then plotted on the proper soil type line, and a line was drawn through the points representing the same cover. The values at the intersection of the cover and soil-type lines were taken from this diagram and listed on the left of Table DA-13 as spring values.

Where runs were made on the same cover and soil-type during more than one season, the values were plotted to determine the relationship between spring and summer, and between spring and fall. By using this relationship, summer and fall values were added to Table DA-13.

It was then necessary to determine the relation between the values of ϕ at a certain time and the values of f_c. To do this, the values of ϕ at 1.4 hours were plotted against f_c (Figure DA-7). With this relation established, all values of f_c were converted to ϕ values as shown on the right of Table DA-13.

As it is desirable to have only one curve to represent either a soil type or cover type, it was necessary to determine which would provide the most accurate results. By plotting ϕ curves for all covers on Knox soil, a wide variation in the curves was found. However, when plotting ϕ curves for all soil types on corn, there was a very minor variation in the curves. Therefore, all ϕ curves were averaged for like cover types by averaging the value of ϕ at 0.1, 0.2, 0.3, 0.4, 0.6, 0.8, 1.0 and 1.4 hours. Figure DA-8 shows the average curves. The final ϕ curves plotted to the scale of the storm diagram are shown in Figures DA-9, DA-10, DA-11, DA-12 and DA-13. On these figures the curve designated, $\Sigma < 0.1$, is equivalent to the dry infiltration run while the one marked $\Sigma > 0.7$ is the curve representing the wet run. Curves of Σ equal 0.2 and Σ equal 0.5 were added to cover intermediate moisture conditions. The determination of Σ values for storms is discussed in the body of Appendix D.

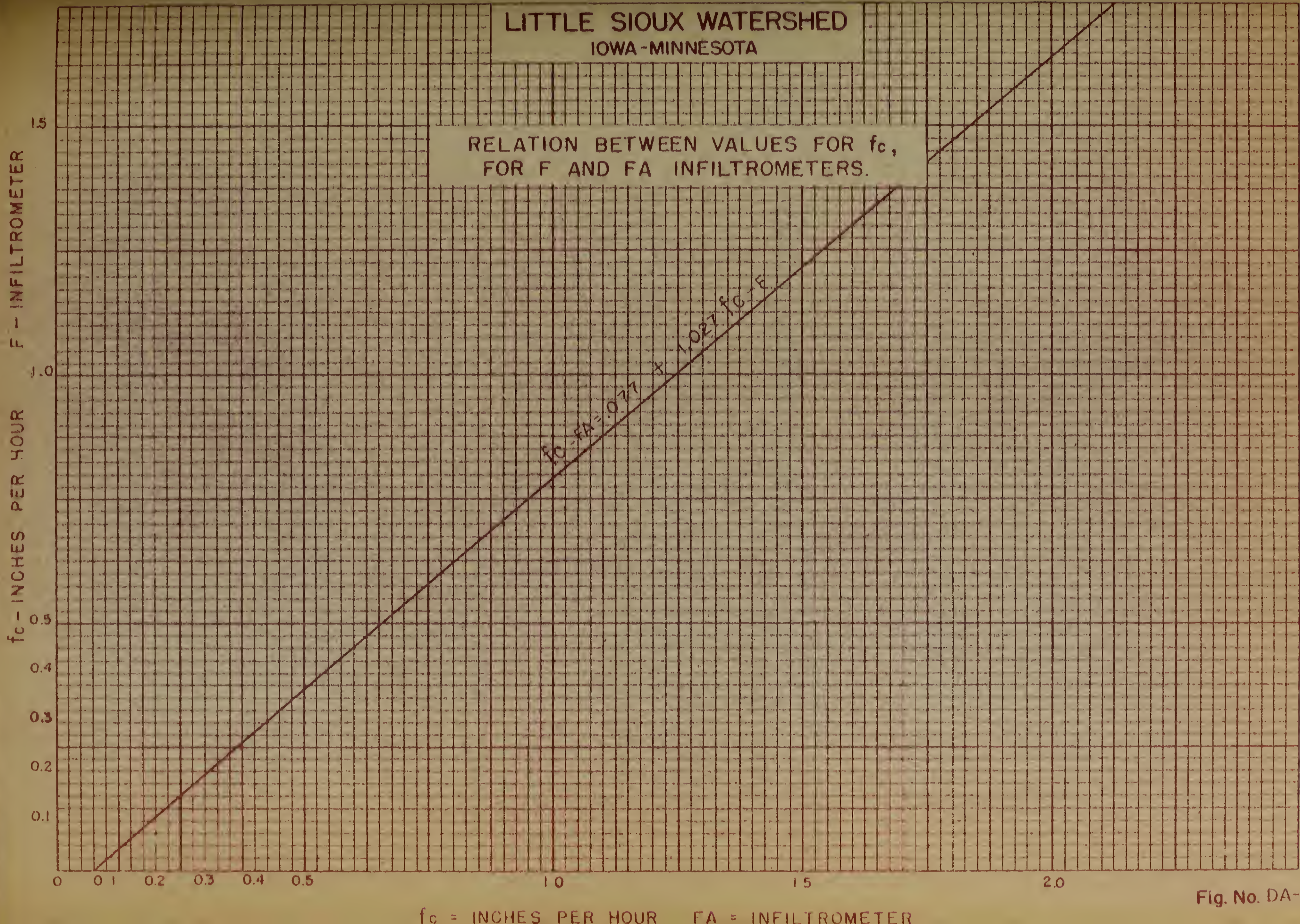

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
RELATION BETWEEN VALUES FOR fc, FOR F AND FA INFILTROMETERS.
fc-FA = 0.77 + 1.027 fc-F
fc - INCHES PER HOUR F - INFILTROMETER
fc = INCHES PER HOUR FA = INFILTROMETER
0
0.1
0.2
0.3
0.4
0.5
1.0
1.5
2.0

Fig. No. DA-4

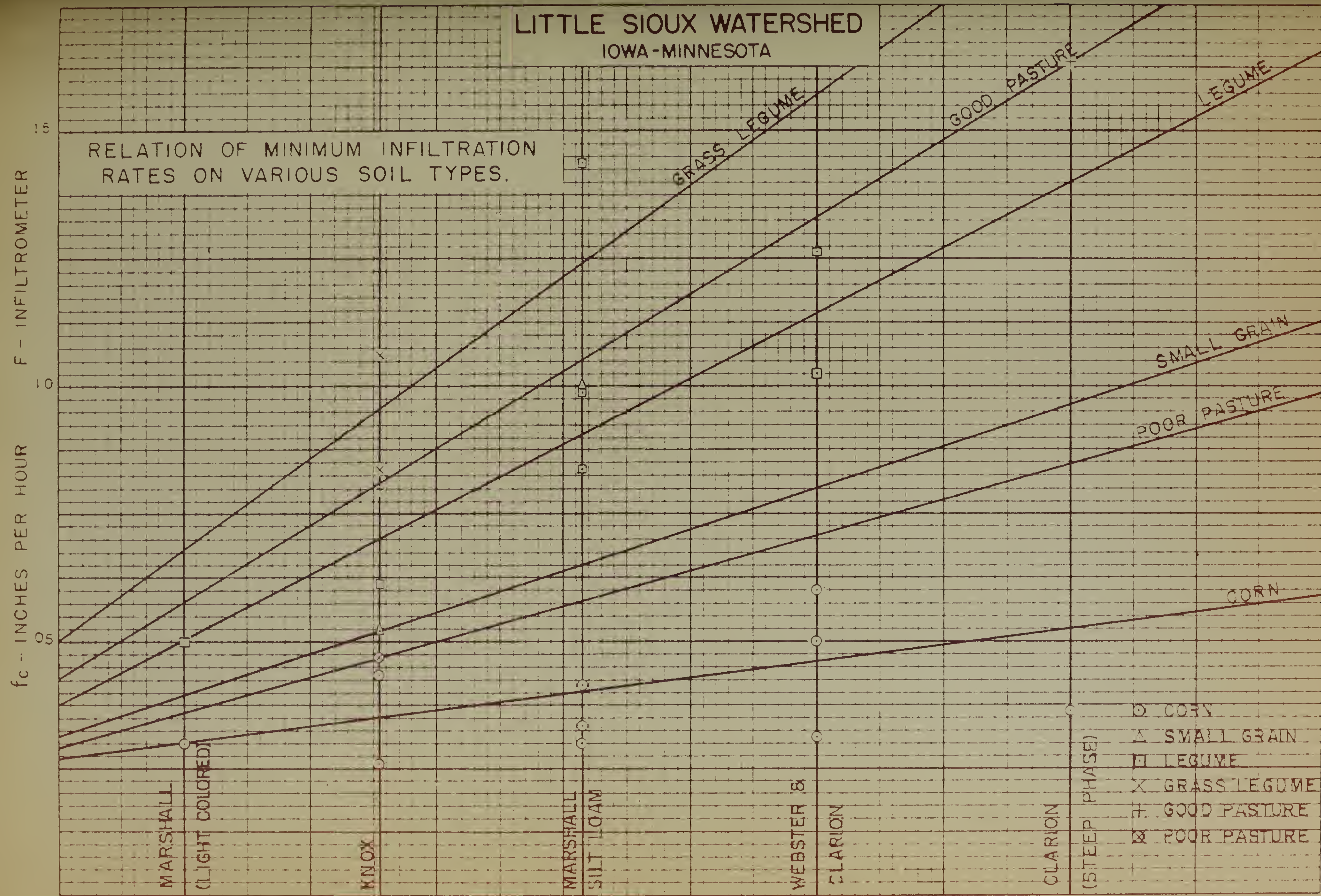
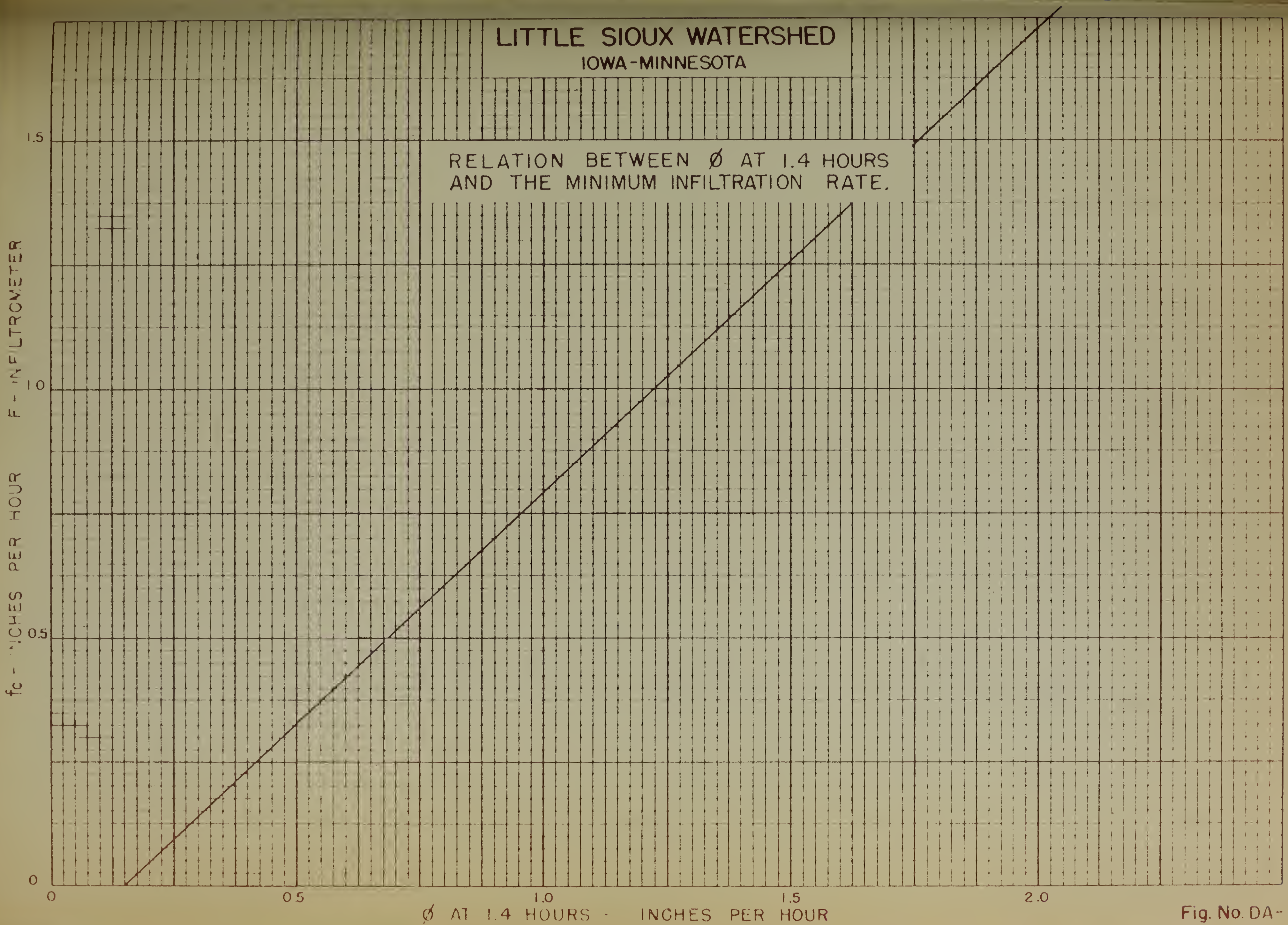
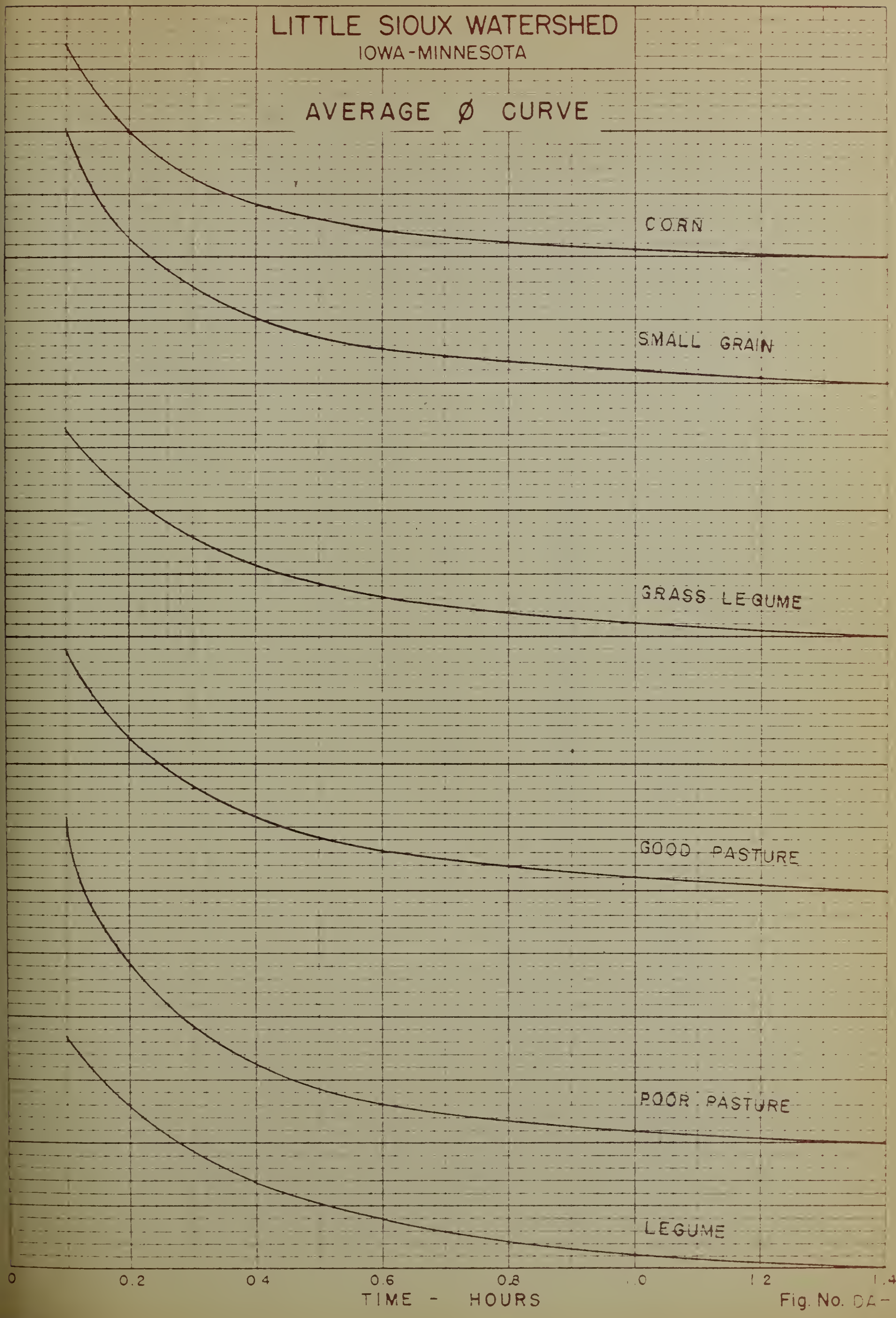

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
RELATION OF MINIMUM INFILTRATION RATES ON VARIOUS SOIL TYPES.
F - INFILTROMETER
f_c - INCHES PER HOUR
1.5
1.0
0.5
GRASS LEGUME
GOOD PASTURE
LEGUME
SMALL GRAIN
POOR PASTURE
CORN
MARSHALL (LIGHT COLORED)
KNOX
MARSHALL SILT LOAM
WEBSTER & CLARION
CLARION (STEEP PHASE)
CORN
SMALL GRAIN
LEGUME
GRASS LEGUME
GOOD PASTURE
POOR PASTURE

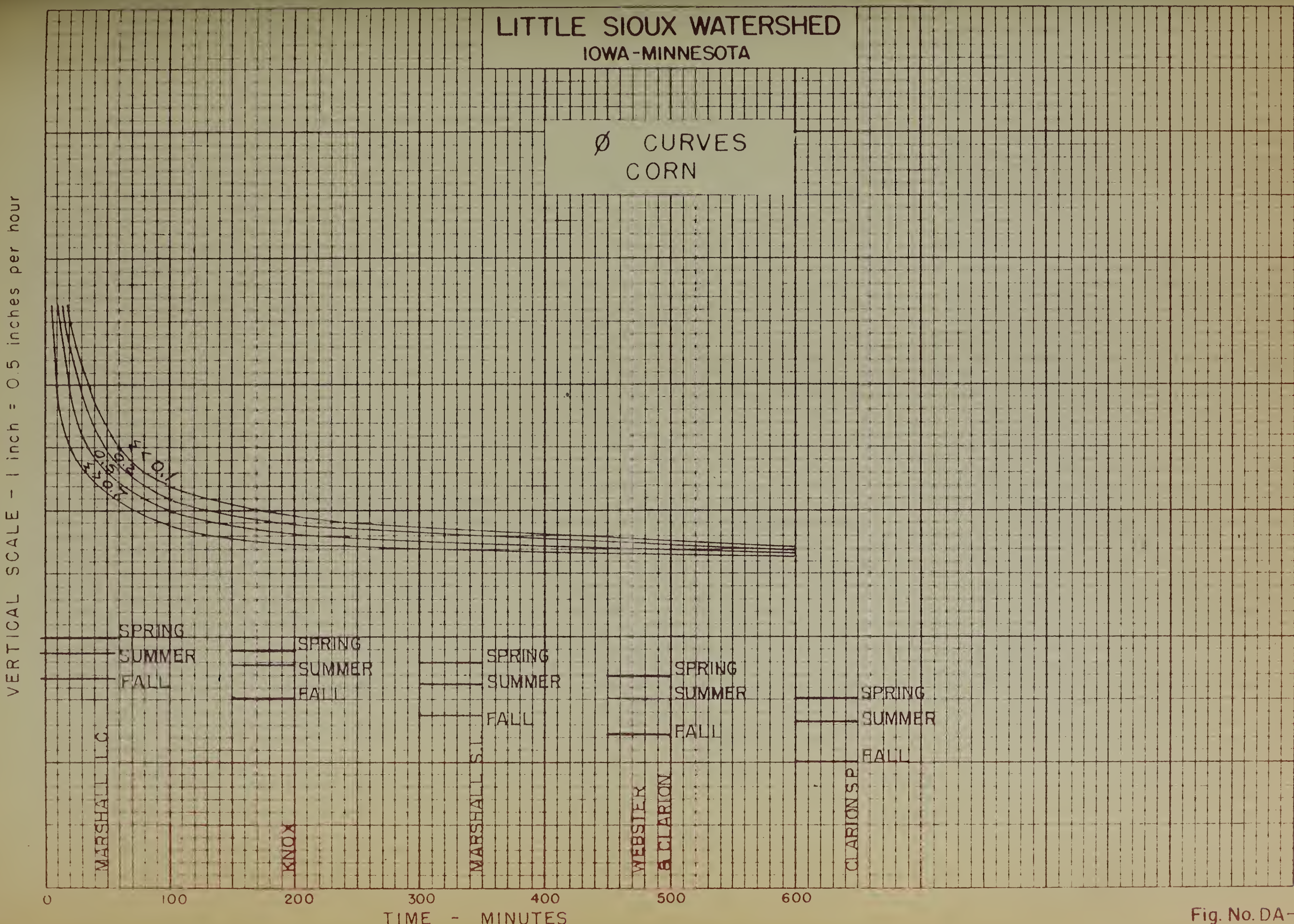
Fig. No. DA-5


LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
RELATION BETWEEN Ø AT 1.4 HOURS
AND THE MINIMUM INFILTRATION RATE.
1.5
1.0
0.5
0
f_c - INCHES PER HOUR F - INFILTROMETER
0
0.5
1.0
1.5
2.0
Ø AT 1.4 HOURS - INCHES PER HOUR
Fig. No. DA-6



LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
AVERAGE Ø CURVE
CORN
SMALL GRAIN
GRASS LEGUME
GOOD PASTURE
POOR PASTURE
LEGUME
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
TIME - HOURS

Fig. No. DA-7



LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
Ø CURVES
CORN
0.1
SPRING
SUMMER
FALL
MARSHALL L.C.
KNOX
MARSHALL S.L.
WEBSTER & CLARION
CLARION S.P.
0
100
200
300
400
500
600
TIME - MINUTES
VERTICAL SCALE - 1 inch = 0.5 inches per hour

Fig. No. DA-8

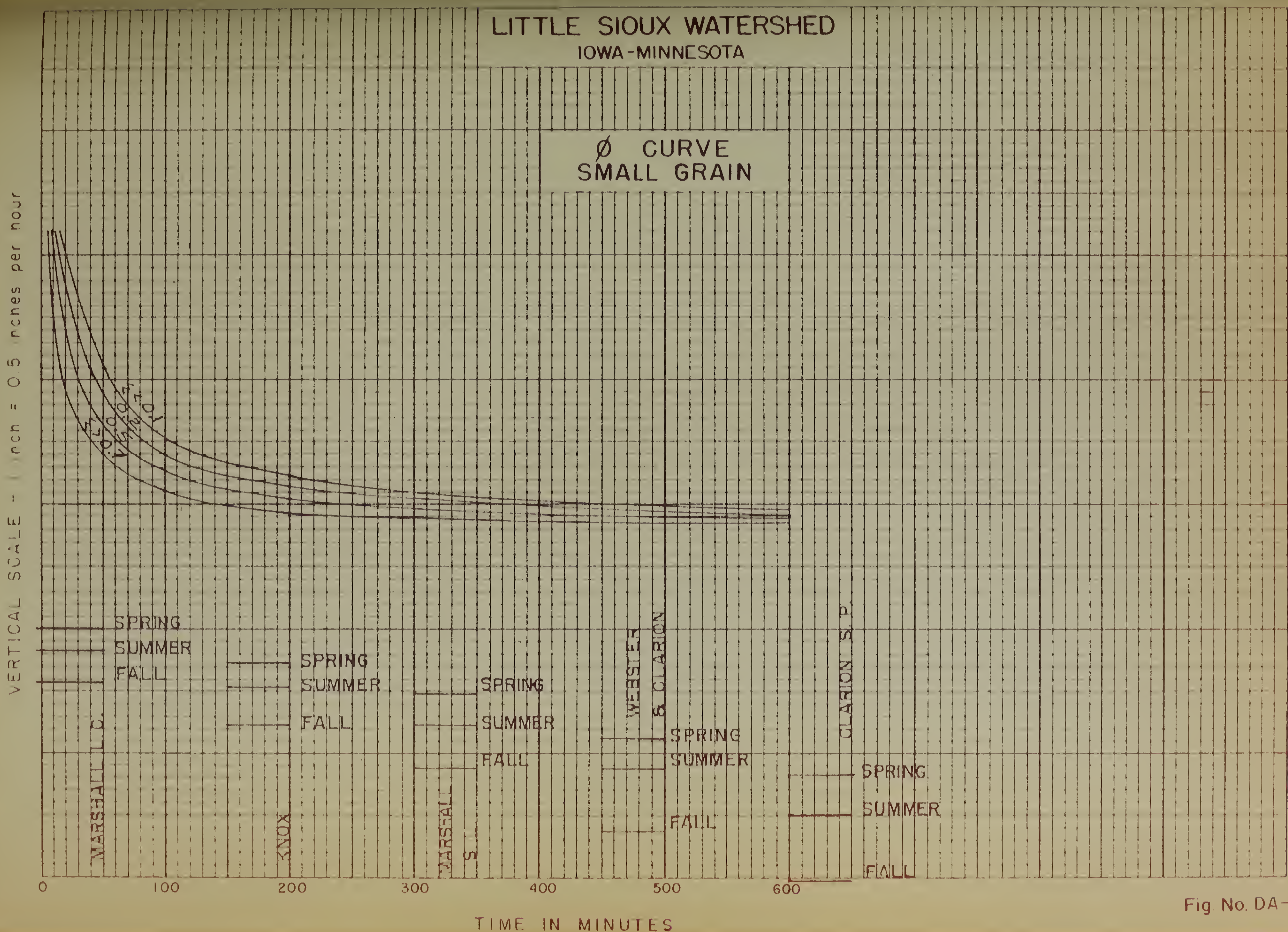
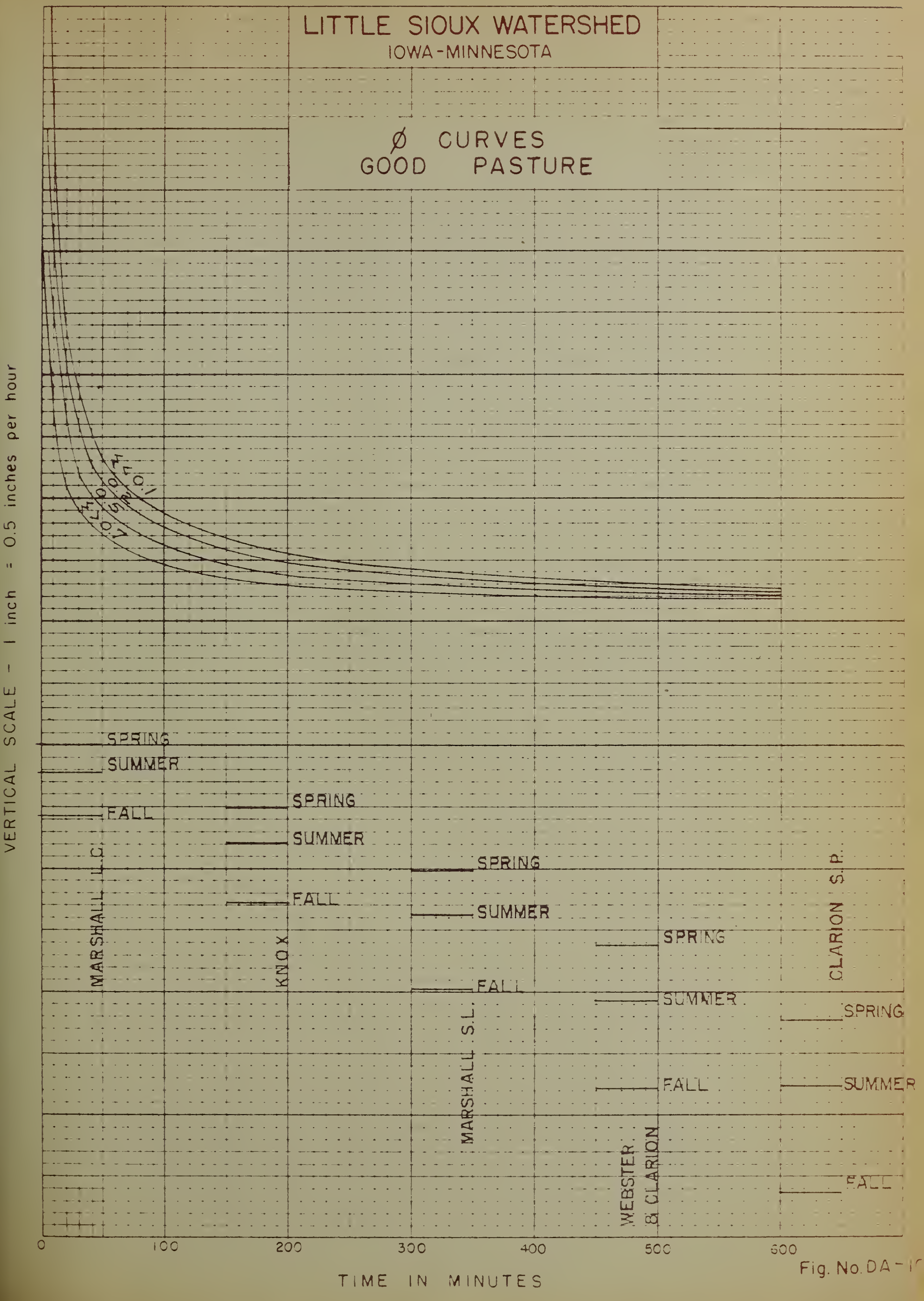
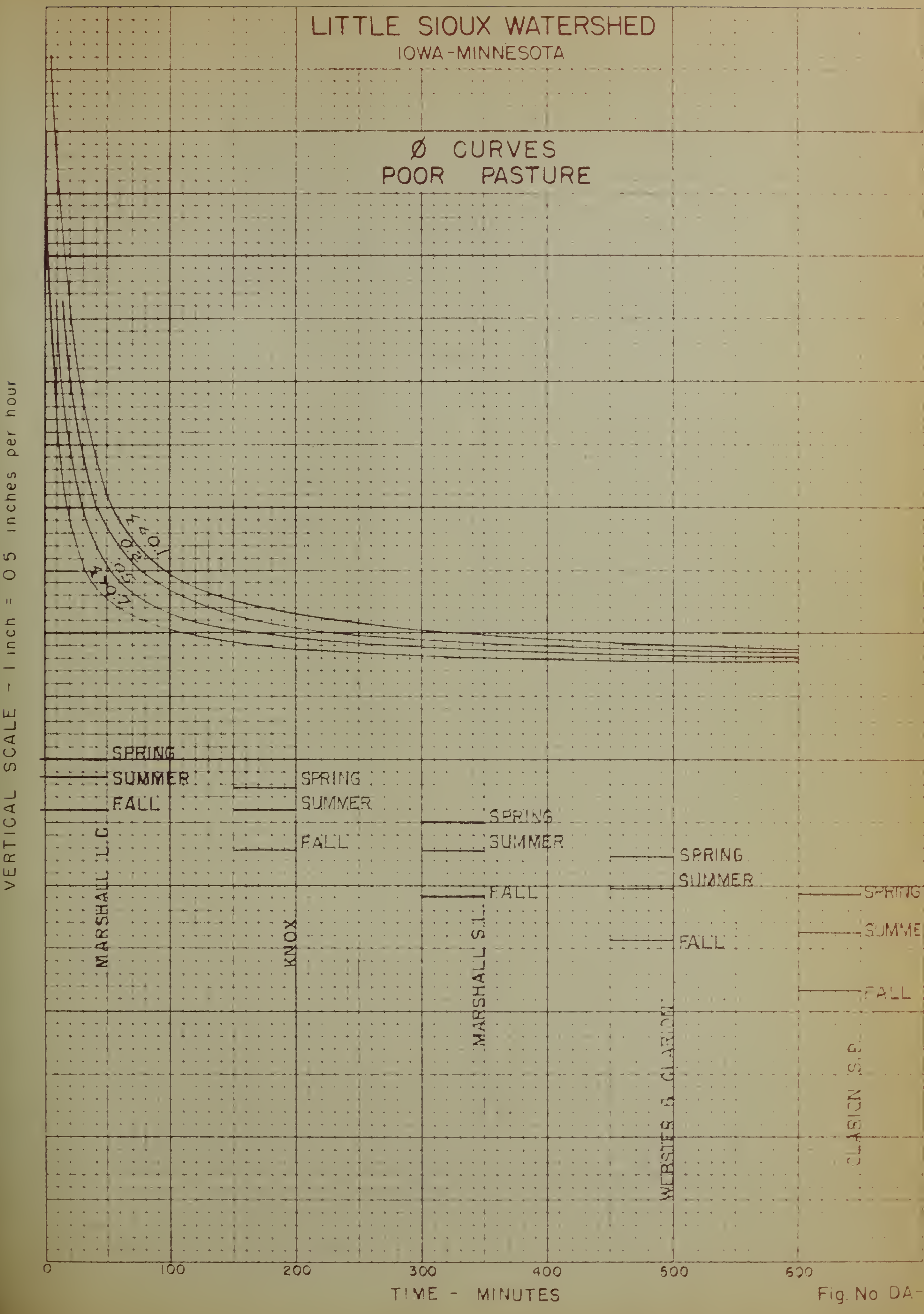

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
Ø CURVE
SMALL GRAIN
VERTICAL SCALE - 1 inch = 0.5 inches per hour
TIME IN MINUTES
0
100
200
300
400
500
600
SPRING
SUMMER
FALL
MARSHALL L.C.
KNOX
MARSHALL S.
WEBSTER & CLARION
CLARION S.P.

Fig. No. DA-9



LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
Ø CURVES
GOOD PASTURE
0.4
0.5
0.7
1.0
VERTICAL SCALE - 1 inch = 0.5 inches per hour
SPRING
SUMMER
FALL
MARSHALL L.C.
KNOX
MARSHALL S.L.
WEBSTER & CLARION
CLARION S.P.
0
100
200
300
400
500
600
TIME IN MINUTES

Fig. No. DA-1


LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
Ø CURVES
POOR PASTURE
VERTICAL SCALE - 1 inch = 0.5 inches per hour
TIME - MINUTES
0
100
200
300
400
500
600
SPRING
SUMMER
FALL
MARSHALL L.C.
KNOX
MARSHALL S.L.
WEBSTER & CLARION
CLARION S.L.
Fig. No DA-

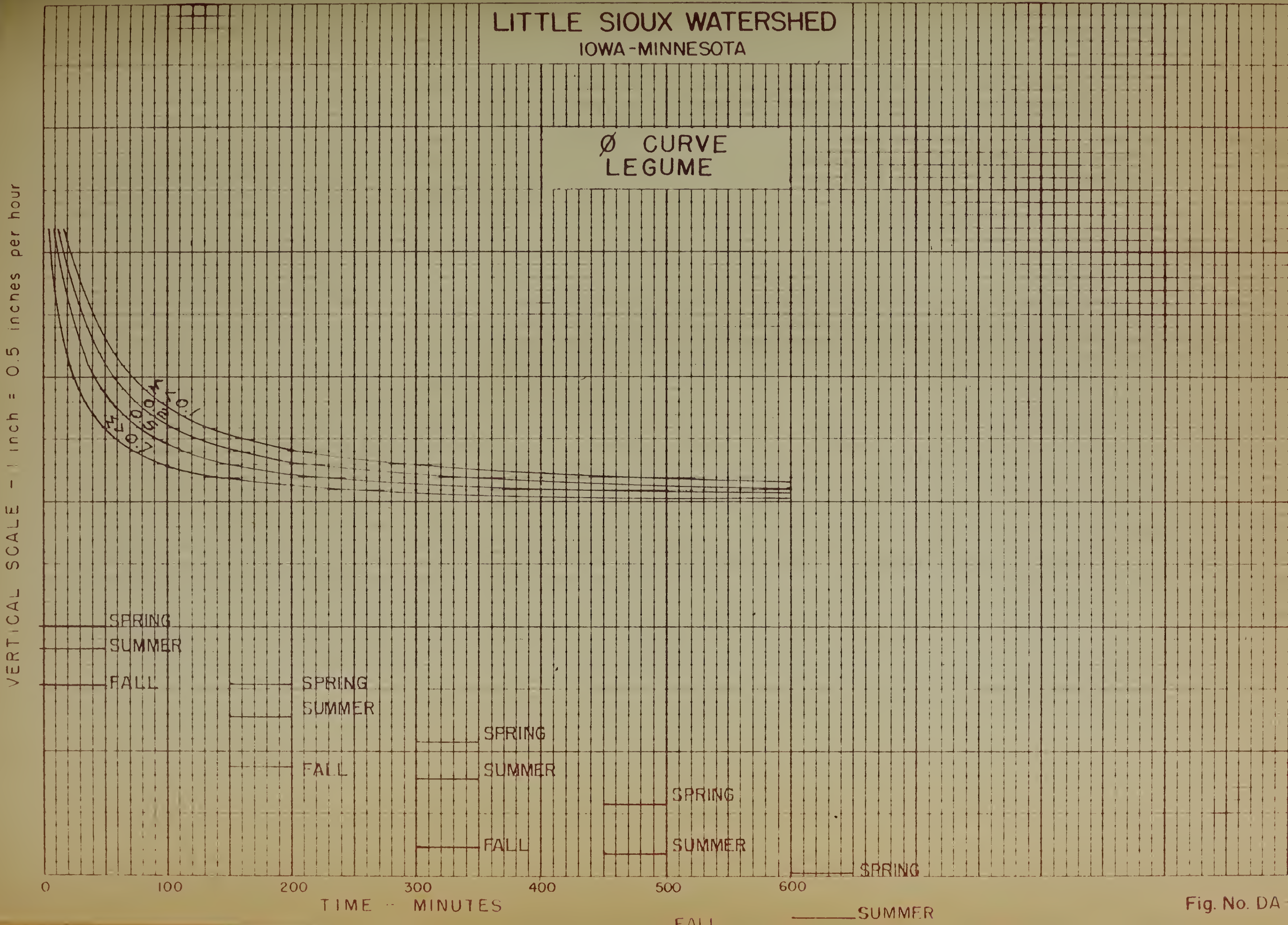

LITTLE SIOUX WATERSHED
IOWA-MINNESOTA
Ø CURVE
LEGUME
K = 0.1
0.2
0.5
K = 0.7
SPRING
SUMMER
FALL
SPRING
SUMMER
FALL
SPRING
SUMMER
FALL
SPRING
SUMMER
SPRING
SUMMER
FALL
VERTICAL SCALE - 1 inch = 0.5 inches per hour
0
100
200
300
400
500
600
TIME - MINUTES

Fig. No. DA-12

TABLE DA-12. MINIMUM INFILTRATION RATES (f_c) FOR F AND FA INFILTROMETERS OBTAINED BY FIELD RUNS AND THEIR EQUIVALENT f_c VALUES FOR F INFILTROMETERS

Soil	Season	Field Data						Equivalent F Values					
		Corn	Small Grain	Legume	Grass Legume	Good Pasture	Poor Pasture	Corn	Small Grain	Legume	Grass Legume	Good Pasture	Poor Pasture
		0.44F		0.49F									
Light	Spring	0.38FA						0.30		0.49			
Colored	Summer												
Marshall	Fall												
		0.35F		0.51F									
Knox	Spring	0.52FA	0.61FA	0.70FA	1.16FA	0.90FA	0.56FA	0.43	0.52	0.61	1.06	0.80	0.47
	Summer	0.35FA			0.94FA			0.27			0.84		
	Fall												
		0.30F		0.99F									
Marshall	Spring	0.39FA		1.08FA				0.30		0.99			
silt	Summer	0.42FA	1.09FA	0.93FA				0.33	1.00	0.85			
loam	Fall	0.49FA	1.09FA	1.55FA				0.41	1.00	1.43			
Webster	Spring	0.40FA		1.37FA				0.32		1.26			
	Summer	0.59FA		2.03FA				0.50		1.91			
	Fall												
Clarion	Spring	0.68FA		1.12FA				0.60		1.02			
	Summer												
	Fall												
Clarion	Spring	.46FA				1.77FA		0.37				1.63	
steep	Summer												
phase	Fall												

TABLE DA-13. MINIMUM INFILTRATION RATES (f_c) FOR F INFILTROMETER AND Ø VALUES AT 1.4 HOURS

Soil	Season	Values of fc						Values of Ø					
		Corn	Small Grain	Legume	Grass Legume	Good Pasture	Poor Pasture	Corn	Small Grain	Legume	Grass Legume	Good Pasture	Poor Pasture
Light colored Marshall	Spring	.30	.40	.49	0.67	.57	.36	.47	.58	.66	.87	.76	.53
	Summer	.36	.47	.57	.80	.67	.42	.54	.66	.75	.99	.87	.60
	Fall	.43	.57	.71	.97	.82	.51	.64	.79	.90	1.19	1.04	.73
Knox	Spring	.35	.52	.69	1.06	.80	.47	.52	.71	.89	1.28	1.01	.65
	Summer	.42	.62	.82	1.26	.95	.56	.59	.81	1.02	1.46	1.15	.74
	Fall	.50	.74	1.00	1.52	1.15	.67	.71	.97	1.22	1.75	1.39	.89
Marshall silt loam	Spring	.40	.65	.90	1.33	1.04	.58	.57	.84	1.12	1.58	1.27	.78
	Summer	.47	.77	1.07	1.57	1.23	.70	.65	.96	1.28	1.80	1.45	.89
	Fall	.57	.93	1.20	1.91	1.50	.85	.78	1.15	1.54	2.19	1.74	1.07
Webster	Spring	.46	.80	1.14	1.57	1.32	.71	.63	1.01	1.38	1.82	1.57	.91
	Summer	.53	.95	1.36	1.87	1.57	.83	.72	1.15	1.57	2.08	1.79	1.04
	Fall	.66	1.15	1.64	2.27	1.88	1.02	.86	1.39	1.89	2.49	2.15	1.25
Clarion loam	Spring	.46	.80	1.14	1.57	1.32	.71	.63	1.01	1.38	1.82	1.57	.91
	Summer	.53	.95	1.36	1.87	1.57	.83	.72	1.15	1.57	2.08	1.79	1.04
	Fall	.66	1.15	1.64	2.27	1.88	1.02	.86	1.39	1.89	2.49	2.15	1.25
Clarion steep phase	Spring	.52	.96	1.40	1.92	1.62	.85	.71	1.17	1.64	2.20	1.88	1.06
	Summer	.62	1.13	1.66	2.27	1.92	1.01	.81	1.33	1.87	2.51	2.14	1.21
	Fall	.75	1.37	2.01	2.76	2.32	1.22	.97	1.60	2.25	3.02	2.58	1.45